THE STATE AGRICULTURAL COLLEGE
OF COLORADO

THE FORTY-SECOND ANNUAL REPORT

— OF —

The Colorado Agricultural Experiment Station

FOR THE YEAR 1929

The Colorado Agricultural College

FORT COLLINS, COLORADO

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	Assistant in Mechanical Engineering

FINANCIAL REPORT OF THE COLORADO EXPERIMENT STATION

For the Fiscal Year ending June 30, 1929

	Hatch Fund	Adams Fund	Purnell Fund	State Mill Levy Fund	Special Fund	Pure Seed Fund	Irrig. Cash Fund	Total Funds
DR.								
Balance, July 1, 1928	...	...	...	$ 19,798.84	($ 1,608.56)*	...	($ 740.00)*	$ 17,450.28
From the Treasurer of the United States as per appropriations for the fiscal year ending June 30, 1929, under acts of Congress approved March 2, 1887, (Hatch Fund), March 16, 1906, (Adams Fund), and February 24, 1925, (Purnell Fund)	$15,000.00	$15,000.00	$50,000.00	...	...	...	...	80,000.00
Other sources than the United States				108,065.76	44,992.46	16,000.00	3,517.11	172,575.33
	$15,000.00	$15,000.00	$50,000.00	$127,864.60	$43,383.90	$16,000.00	$2,777.11	$270,025.61
CR.								
To Salaries	14,567.80	15,000.00	40,711.85	34,583.16	24,453.94	362.50	1,084.00	130,763.25
Labor			1,352.50	23,053.70	660.42	22.65	113.00	25,202.27
Stationery and Office Supplies			254.78	1,093.72	175.91	69.68	56.30	1,650.39
Scientific supplies, consumable			552.70	1,773.42	1,842.67	...	1.95	4,170.74
Feeding stuffs			194.36	11,252.19	175.74	...	...	11,622.29
Sundry supplies			141.71	3,238.25	451.19	111.55	46.06	3,988.76
Fertilizers			...	57.00	...	...	...	57.00
Communication service			71.04	1,052.82	237.22	139.22	1.80	1,502.10
Travel expense			3,463.39	9,406.23	507.77	313.00	621.72	14,312.11
Transportation of things			2.41	615.84	57.27	1.30	...	676.82
Publications	432.20		303.20	4,144.76	76.90	...	197.35	5,154.41
Heat, light, water, power			168.00	2,354.39	142.61	...	...	2,665.00
Furniture, etc.			872.96	973.75	42.89	542.75	...	2,432.35
Library			202.44	953.65	36.55	...	...	1,192.64
Scientific equipment			1,071.95	2,154.63	199.87	1,115.25	352.77	4,894.47
Livestock			48.00	12,842.65	1,154.40	...	...	14,045.05
Tools, machinery, appliances			9.25	4,134.62	4.60	54.88	588.65	4,792.00
Buildings and land			219.46	4,283.49	1,268.12	...	96.99	5,868.06
Contingent expenses			360.00	384.26	103.00	...	...	847.26
Total expenditures	$15,000.00	$15,000.00	$50,000.00	$118,352.53	$31,591.07	$ 2,732.78	$3,160.59	$235,836.97
Balance on hand June 30, 1929	...	...	...	9,512.07	11,792.83	13,267.22	(383.48)*	34,188.64
Grand Total	$15,000.00	$15,000.00	$50,000.00	$127,864.60	$43,383.90	$16,000.00	$2,777.11	$270,025.61

(*Overdraft)

LETTER OF TRANSMITTAL

To His Excellency, William H. Adams, Governor of Colorado:

In accordance with the law of Congress establishing Agricultural Experiment Stations, I have the honor to transmit the Forty-second Annual Report of the Colorado Agricultural Experiment Station for the state fiscal year, December 1, 1928 to November 30, 1929, and the financial statement for the federal fiscal year, July 1, 1928 to June 30, 1929.

The report contains brief summaries of the work done by those in charge of the different sections of the Experiment Station, as well as a full list of projects upon which work has been done during the year.

C. P. GILLETTE, Director

Agricultural Experiment Station
Fort Collins, Colorado
December 1, 1929

AGRICULTURAL DIVISION

Report of the Director

To the President:

I am presenting the forty-second annual report of the Colorado Agricultural Experiment Station which covers the investigational work carried during the 12 months just closing, and gives the financial statement covering the federal fiscal year from July 1, 1928 to June 30, 1929.

The departments in which work is being carried have not changed since 1 year ago. The number of projects has increased from 71 to 80. The number of workers is practically the same. A few new projects have been undertaken and a few old ones have been completed. There have been a number of resignations of good workers to take positions in other institutions at higher salaries. In some cases this has interfered rather seriously in the investigational work carried here. The institution has reached its maximum income until some additional federal or state appropriations are made for the extension of its work which really is very much needed. During the past year there has been some extension of the work at Akron, at Rocky Ford and at Avon. Increased budgets are much needed for work at Cheyenne Wells, Fort Lewis and at the home station, but no extension of work can be undertaken without reducing the work in some of the investigations that are already in progress.

As in the past, I am glad to report that, on the whole, a very good spirit of cooperation exists among the workers in the different sections of the station, and considerable cooperative work is being carried with bureaus of the U. S. Department of Agriculture. I feel that there is a need of a fuller correlation of the station work with the work of the extension division and shall work to this end in the immediate future.

At the recent meeting of the Association of Land Grant Colleges and Universities, there was expressed a rather strong general sentiment to the effect that investigational work in the immediate future should be stressed along the lines of economic and quality production and in fundamental researches which will lay the basis for the building of a stable agriculture in the country. Fortunately we have been directing our attention strongly along these lines for some years, and shall continue to do so for some time to come.

It becomes more and more evident as the years go by that it is the quality rather than the quantity of a farm product that deter-

mines whether or not it will bring a net return to the producer. In all sections of the station a special effort should be made to direct the investigations to economic production rather than quality production. Researches that will give information upon which to base more economic marketing of crops are also needed.

The station has spent considerable money in permanent improvements at Rocky Ford, Avon and Austin during the year.

The station has published 17 bulletins and 4 press bulletins during the year, and station workers have furnished manuscripts for a number of extension bulletins and scientific articles published in technical journals of the country.

I am giving below the projects upon which work has been carried during the past year.

AGRICULTURAL DIVISION

Agronomy Section

Relation of Soil Moisture, Structural Development and Acre Yields in Small Grains. Adams and State funds.
Correlation of Characters in Grains. Hatch and State funds.
High-altitude Crops. State funds.
Plains Crops and Management. State funds.
Improved Seed. State funds.
Control of Excessive Soil Nitrates in the Arkansas Valley. Purnell and State funds. (Co-op. with Bacteriology)
Studies in the Control of Bacterial Wilt and Winter-killing. Purnell and State funds. (Co-op. with Bacteriology)

Animal Investigations Section

Ration Experiments with Cattle. State funds.
Summer Cattle-fattening Experiments. State funds.
Range and Pasture Improvement. State funds. (Co-op. with Botany).
Ration Experiments with Lambs. State funds.
Cornfield Lamb-feeding Experiment. State funds.
Summer-fallow Experiment at Akron, Colo. State funds.
Winter Maintenance of Breeding Ewes. State funds.
Poultry Experiments. State funds.
Beet By-products for Fattening Beef Calves. Purnell fund.
Comparative Value of Different Kinds of Molasses in Lamb-fattening Rations. Purnell and State funds.
Hog Feeding in the San Luis Valley. State funds.
Utilization of Dryland Feeds. State funds.

Bacteriology Section

Heat-resisting Bacteria in Fresh and Canned Vegetables. Adams fund.

Value of Certain Carbon Compounds as Sources of Energy for Azotobacter. Adams fund.

Natural Innoculation of Colorado Soils with Legume Bacteria. Hatch and State funds.

Winogradsky Method of Testing Soil Deficiencies. Purnell fund.

Control of Excessive Soil Nitrates in the Arkansas Valley. Purnell and State funds. (Co-op. with Agronomy).

Studies in the Control of Bacterial Wilt and Winter-killing. Purnell and State funds. (Co-op. with Agronomy).

Botany Section

Range and Pasture Improvement. Purnell and State funds. (Co-op. with An. Inv.)

Cereal and Field-crop Disease Studies. Hatch and State funds.

Truck-crop Disease Studies. Hatch and State funds.

Identification of Species of Beta and Brassica. Purnell fund.

Weed Control. State funds.

Chemistry Section

Deterioration of Hays Resulting from Rain. Adams, Hatch and State funds.

Entomology Section

Plant-louse Investigations. Adams fund.

Ants in Relation to Plant Lice. Hatch and State funds.

Codling-moth Studies. Hatch and State funds.

Codling-moth Control by Means of an Egg Parasite. Purnell and State funds.

Grasshopper Control. State funds.

Potato Flea-Beetle. State funds.

General Insect Investigations. State funds.

Rodent Poisoning. State funds.

Rodent Life Habits. State funds.

Colorado Insect Fauna. State funds.

Resistance of Bees to American Foul-brood. State funds.

Economics and Sociology Section

An Economic Study of the Peach Industry in Colorado. Purnell fund. In co-operation with U. S. Dept. of Agriculture.

An Economic Study of Farm Organization and Management in the Greeley Area in Northeastern Colorado. Purnell fund.

A Study of Costs and Methods of Producing Cattle and Sheep on the Range in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.

A Study of the Social Status of the Spanish-speaking People in Rural Colorado. Purnell fund.

A Study of Taxation in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.

A Study of the Methods of Storage and Marketing Practices which obtain in handling Potatoes on Farms in the San Luis Valley. State funds. In cooperation with Colorado Division of Markets.

An Economic Study of the Apple Industry of Colorado. Purnell fund. In co-operation with U. S. Dept. of Agriculture.

An Economic Study of Land Utilization in Northwestern Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.

A Study of the Major Types of Cooperative Organizations of Associations in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.

Home Economics Section

The Baking of Flour Mixtures at High Altitudes. Part II. Purnell fund.

Horticultural Section

Potato Varieties. State funds.

Garden-pea Variety and Breeding. State funds.

Onion Projects. State funds.

Development of a Tipburn-resistent Variety of Head Lettuce. Purnell fund.

High-altitude Vegetable Production. State funds.

Garden Pod Bean Project. State funds.

Orchard Management. State funds.

Small Fruits. State funds.

Certified Seed Potatoes. State funds.

Irrigation Investigations

Measurement of Water. Hatch and State funds.

Evaporation. Hatch and State funds.

(a) From a Free Water Surface.

(b) From Moist Soils.

Meteorology. State funds.

Pumping for Irrigation and Drainage. State funds.

Pathology Section

Sheep Losses in Feedlots. Hatch fund.
Contagious Abortion. Hatch and State funds.
Coccidiosis in Cattle. Purnell fund.
Death Losses in Lambs on Heavy Grain Feed. Purnell and State funds.
Icterohematuria. State funds.
General Disease Investigations. State funds.

Veterinary Section

Animal Diseases. State funds.

ENGINEERING DIVISION

Civil Engineering Section

Road Materials of Colorado. State funds.
Frost Heaving Investigation on Concrete Slabs. State funds.
Capping of Concrete Cylinders. State funds.
Light Asphaltic Road Surfaces. State funds.

Mechanical Engineering Section

A Proximate Analysis of Colorado Coals. State funds.
Gasoline Economy in Automobile Engines. State funds.
Drying Potatoes for Stock Feed. State funds.

Following are brief statements from section heads concerning the investigational work in the several sections. I hope you will find it possible to read these rather carefully as I wish to avoid, in a short report like this, calling attention to outstanding results in one or two departments and appear to overlook equally good work in others.

Respectfully submitted,
C. P. GILLETTE, Director

AGRONOMY SECTION

To the Director:

I am submitting my annual report for the period ending November 30, 1929.

The staff of the Agronomy Section has changed somewhat during this period. Roy D. Hockensmith who has both teaching and experiment station duties, took the place in soils made vacant by the resignation of Rudger H. Walker. Mr. Robert Gardner became soil chemist at Rocky Ford replacing Justus C. Ward. With the resig-

nation on the teaching staff of Clark H. Alford, we have employed Warren H. Leonard who will have teaching and experiment station duties. The staff as now organized consists of: Alvin Kezer, chief; D. W. Robertson, associate, C. Warren Deming, assistant; Roy D. Hockensmith, part-time assistant and Warren H. Leonard, part-time assistant located at Fort Collins, J. W. Adams located at Cheyenne Wells, Robert Gardner at Rocky Ford and Dwight Koonce at Fort Lewis. Thru cooperation of dryland agriculture, Joseph F. Brandon functions as an associate at Akron.

During the year the work has been on critical-period project, improved-seed project, methods of determining fertilizer needs, alfalfa-disease control, residual effects of irrigation water and some minor projects at Fort Collins.

Under the improved-seed project, we carried on a series of experiments in possible pasture crops and crop mixtures. These experiments have shown adapted species. They have also shown the survival of these adapted species in associations. We have harvested the forage produced in two ways,—first, as a meadow crop and second, by frequent cuttings to simulate animal grazing. This work has now gone far enough so that we know species survival and association relationships—that is, how species survive in the pasture mixtures. The better of these mixtures should now be subjected to actual grazing so as to find out the effect of tramping and the selective eating by the animals. Enough information is at hand to add quite materially to our knowledge of species adaptation and species relationships in pasture mixtures.

The methods of determining fertility needs are carried on in cooperation with the Bacteriology Section. The Neubauer, Winogradsky and Hofer methods have been tested extensively in the laboratory. All of these methods are checked by actual fertilizer treatment in the field. I think we have gone far enough to indicate the Hofer method can be discarded as useless in our territory. Both the Neubauer and Winogradsky methods appear to give results comparable to actual field tests. We appreciate that 1 year's work is not sufficient but all work this year correlates the laboratory indications with actual field results. The economic implications of this project are very important. If it can be shown that a reliable indication can be obtained in the laboratory for fertilizer practice, it will obviate the necessity of long-time experimental fertilizer application plats thruout the state. Up to the present time, long-time experiments where the fertilizers are actually tried in the field have been the only reliable method of getting the fertilizer needs. While the method was reliable, it required a number of year's work in each case. It

also had to be carried out on each considerable soil type or soil series. If we can reliably determine the fertilizer needs in the laboratory, this expensive work can be eliminated.

In one case, the application of phosporus to sugar beets gave a 300 percent increase in yield. Both the Neubauer and Winogradsky tests indicated need for phosporus. On those farms where good farm practices have been carried out and where yields were high, neither the Winogradsky or Neubauer tests indicated any need for fertilizer. On such places, the fertilizer would not improve the yield. We appreciate that further and extended tests are necessary, but the preliminary work of this year indicates a wonderful correlation by the laboratory results and field requirements.

The alfalfa-disease-control project has been attacked from two standpoints. First has been the search for alfalfa varieties which may be resistant to the disease. These varieties are planted on lands known to be infected. Second, we are trying soil treatments which lend some hope of building up physiological resistance in the crop itself.

It can be appreciated that a successful solution of the alfalfa-disease problem will mean much to our agriculture when we consider that in 1928 better than 30 percent of the alfalfa of Larimer County, about 40 percent of Weld County and about 25 percent of Boulder County was killed out by the alfalfa wilt. It takes time in the solution of this problem because the disease seems to require about 3 years to obtain full development.

At Akron, we are carrying projects on the rate and date of planting small grains and corn, tillage and cultural experiments, plains forage crops and variety tests. Work on barley, especially, is promising. It indicates that the broad-leafed barleys are not adapted to dryland growing.

Our work has been carried a sufficient number of years so we are now ready to recommend dryland barley varieties. Club Mariout, Selection Strain from White Smyrna and Flynn are our superior dryland barleys. One year with another, barley will produce as much feed grain per acre as corn.

We have been experimenting with forage crops for years. One of the so-called forage crops, hog millet or proso, is developing into a feed grain crop. Hog millet has been under experiment at the Akron station and somewhat also at Cheyenne Wells station for over 20 years. Back in 1913-14, a number of farmers in Northeastern Colorado were induced by us to try feeding hog millet to fatten livestock. The suggestion was carried out by one or two farmers who reported

excellent success. Similar farmer feeding was conducted in Southwestern Nebraska. In spite of these demonstrations, hog millet did not gain much popularity. However, with the definite experimental work of the Animal Investigation Section in the last 2 or 3 years, the crop has suddenly jumped into popularity as a grain feed crop. It is well adapted to practically all of the northeastern section. Its water requirements are low and it grows in a short season.

At Rocky Ford our studies have been continued. We believe that we now have sufficient data to justify an extended study and probably a number of publications on different phases of the subject. If we can make suitable personnel arrangements, we hope to have Mr. Gardner come to Fort Collins during the winter and devote all of his time to such data studies.

The work at Fort Lewis is for high-altitude agriculture, and consists of variety adaptation work with grains, pasture, meadow and forage crops, together with a study of cultural and irrigation practices. Data obtained at Fort Lewis for this period consist of one publication—our wheat bulletin. Other data are to appear in forthcoming publications on barley, oats and probably pasture crops.

At Cheyenne Wells, work has been at a standstill because of no state appropriation. It would not be good policy to divert any small fund from other work to Cheyenne Wells because such a small diversion would not be sufficient to accomplish results and would reduce effective work elsewhere. It would be highly desirable, however, to have the state properly finance work at Cheyenne Wells.

Our plains agriculture which is partially served by Akron needs additional help from experimental work in the mid-region represented by Cheyenne Wells and needs further work in the southeastern region represented by eastern Las Animas and Baca counties. The dryland country straddling the Arkansas Valley has so low a rainfall that at present it should not be dry farmed. By that I mean to say that there are so many dry-farming areas where the rainfall is better adapted for production that they should be studied and developed first. Dryland agriculture is an important part of Colorado's agricultural production. Over 70 percent of the wheat, about 80 percent of the corn and around 70 percent of the barley are dryland grown. Practically all of the millets including proso, the major part of the sorghums, nearly all of the beans from a general market consideration, are dryland produced.

The Experiment Station needs to be in advance of agricultural needs and practices in this important field.

In addition to the work just reported, Professor J. W. Sjogren, teacher in farm mechanics has spent his summers and a portion of

his school year studying certain farm engineering problems which we designate as farm mechanics. A bulletin is nearly ready for the editor on adobe buildings. Studies have been made for several years, in cooperation with the U. S. Department of Agriculture, on the measurement of hay in the stack. There is much more work of a similar nature that should be undertaken and carried to a conclusion whether that conclusion give favorable or unfavorable results.

We need to know comparative costs of performing many farm operations with horses and tractor power. We need to know the adaptability of different types of tractor power to different lines of farm work, for the double reason of knowing the comparative horse and power adaptability for these operations and to learn the best methods of hitch and power application. We should also learn the limitations of tractor power as compared with horse power.

We are equipped in man power to make these studies but do not have the necessary budget or material equipment.

Respectfully submitted,

ALVIN KEZER, Agronomist.

REPORT OF THE ANIMAL HUSBANDMAN

To the Director:

Following is a report on the various projects carried on by this section:

Beet By-product Rations for Fattening Beef Calves (Purnell)

Wet Beet Pulp for Fattening Beef Calves.—Altho feeders have long recognized the high fattening value of wet beet pulp for aged cattle, there has been very little known concerning its value when fed to calves, and many have considered it too bulky a feed for satisfactory results on the younger animals. An average of two tests recently completed demonstrates clearly that wet beet pulp actually makes a very efficient feed in fattening beef calves as well as older cattle.

Siloed vs. Pressed Beet Pulp.—Wet beet pulp coming directly from the diffusion cells at the factory, contains as high as 95 percent moisture. This "green" pulp is at the present time either siloed at the factory or run thru cold presses and delivered to the feeder as pressed pulp containing about 85 percent moisture. A comparison of fattening rations containing siloed and pressed pulp has indicated that the fattening value is largely dependent on the dry-matter content of the pulp at the time of feeding.

Corn Silage as a Supplement to Wet Beet Pulp.—Because of the limited supply of wet beet pulp available to satisfy a strong demand, feeders often lack sufficient pulp to fatten the desired number of cattle. A test to determine the value of corn silage when used as a supplement to wet pulp has indicated that, altho corn silage is neither as cheap nor efficient as wet pulp at present prices, it may be used to advantage to supplement a limited supply of wet pulp in increasing the number of calves fattened. Seventy-five tons of pulp with grain, cottoncake and hay were sufficient to fatten out only 35 calves. The same amount of wet pulp, with addition of 43 tons of corn silage, proved sufficient to finish 66 calves but at a cost of 64 cents per cwt. more for gains.

The Fattening Value of Sugar-Beet Tops.—Beet tops fed with a basic ration composed of barley, cottonseed cake and alfalfa hay, showed a feed-replacement value of $6.41 per ton of tops fed.

Ration Experiments with Cattle

Comparison of Gains and Cost of Gains on Steer and Open-Heifer Calves.—Open-heifer calves produced only 80 percent as much gain as steer calves fed the same ration over a 203-day feeding period. The feed cost per unit of gain was only 92.7 percent as much for steers as for the open heifers.

Storage Studies with Pressed Beet Pulp.—A comparison of a trench silo and an above-ground straw silo for storing pressed beet pulp showed practically equal losses amounting to 29.21 percent for the trench and 26.89 percent for the straw silo. The cost of the trench silo, however, amounted to only 29 percent the cost of the above-ground straw silo.

Summer Cattle-Fattening Experiment

Beef calves fed thru the winter on a warming-up ration composed largely of roughages, were fattened during the following summer on irrigated pasture and a heavy grain ration. A comparison was made of alfalfa pasture, sweet-clover pasture and a perennial pasture-grass mixture (Morton's), while a mixture of equal parts corn and barley was used for a concentrate. The cheapest gains were secured on the perennial pasture-grass mixture. The highest net profits on pasture were secured where a protein concentrate was added to the perennial pasture-grass mixture, but higher net profits were realized with cattle fattened in drylot. Cattle fattened on irrigated pastures showed a characteristic yellow color in the carcass fat which was partially eliminated where a protein concentrate was added.

Range Management

A study is being made of the carrying capacity of low foothill range in the maintenance of a beef breeding herd. The value of protection to the forage during the early spring growing period is shown thru actual practice. Systematic rotation of cattle on the pastures as a means of increasing forage production is another phase of the investigation. Winter maintenance investigations with heifers are also being conducted.

Cornfield Lamb Feeding

Different methods for lambing down corn have been practiced in an effort to establish an economical practice that will cheapen fattening costs and eliminate excessive death loss. Altho a satisfactory method has not yet been evolved, it is planned to continue this work. With the idea that the pasturing of stock beets (mangels) may offer possibilities in the field-fattening of lambs, some tests in grazing off beets with a supplementary feed of alfalfa hay and with and without grain are being carried on at the present time.

Ration Experiments with Lambs

Barley proved to be a better fattening feed when supplemented with available carbonaceous feeds than when fed alone with alfalfa hay. Fed alone with alfalfa hay, barley produced more growth but less finish than corn. Average results for two feeding tests indicate that a No. 2 grade of barley has 89.4 percent and a No. 3 grade of barley, 83.5 percent the fattening value of corn.

In two fattening tests a No. 2 barley, steamed rolled, showed only 86.7 percent the feeding value of corn. In this test, the addition of .25 pound cottonseed meal to the barley-alfalfa ration increased the gain per lamb 5.25 pounds and produced gain for 91.8 percent the feed cost required with barley and alfalfa alone.

Corn silage fed with the basic ration at the rate of 2.5 pounds per head showed a feed replacement value of $7.45 per ton which was 51.4 percent the value of alfalfa hay. Corn silage had practically 40 percent the feeding value of cut, dried, corn fodder fed with the basic ration at the rate of 1.25 pounds daily, giving the cut fodder a value of $18.63 per ton.

Pressed beet pulp proved by far the most efficient carbonaceous supplement. Costing $2.64 per ton fed, it showed a feed-replacement value of $6.94.

Feed cost of gains on light 40-pound lambs amounted to only 87.5 percent the cost of gains on 60-pound lambs but the lighter lambs did not sell for as high a price per cwt. According to average

results secured, the light lambs purchased at 50 cents per cwt. less than medium weights, would have returned the same profit.

A comparison of narrow panels and self-feeders for feeding long alfalfa hay indicated that self-feeders, all costs included, were more profitable. A 30-pound gain on 1000 lambs cost $3000 with self-feeders and $3156 with panels while there was a difference in total cost of equipment of only $160. A yearly saving of $156 would nearly pay for the feeders in one year.

Comparative Value of Different Kinds of Molasses in Lamb-Fattening Rations (Purnell)

A general summary of more recent lamb-feeding experiments with molasses has indicated a higher value for beet molasses than for cane molasses where proper care has been exercised in gradually introducing the beet molasses into the ration.

With the new barium process for extracting additional sugar from Steffens discard molasses, a new final discard molasses is being produced and used as a stock feed in Colorado. Altho this molasses, called "Johnstown Final Discard," contains a higher percentage of carbohydrate than the Steffens discard molasses, a considerable portion is in the form of trisaccharide, raffinose.

Insistent inquiry from lamb feeders regarding the relative feeding value of cane molasses and the different kinds of beet molasses has made it advisable to test these different kinds of molasses available to Colorado feeders. The first test comparing cane molasses, beet molasses, Steffens discard molasses and Johnstown final discard molasses fed with shelled corn and alfalfa to fattening lambs, indicated that the palatability of the different molasses was practically the same, that the Steffens discard was slightly more efficient than the others, followed in order of efficiency by straight beet molasses, Johnstown discard and cane molasses. This test is being duplicated.

Winter Maintenance of Breeding Ewes

In the range, ewe-maintenance experiment which has been run for 1 year, we can state a few facts which are indicated by this 1 year's work. In the first place it seems to be very desirable to add cottonseed meal to a South Park hay ration, when the results are based on weight alone. The feeding of calcium and of both calcium and phosporous shows some beneficial results, but they are so slight that they may be within the range of experimental error. However, when a chart is made of the weights of these ewes at various times, we note a residual effect of the calcium and phosphorous which later experimental work may prove to be important. For example, during

the time of gestation, calcium or calcium and phosphorous did not affect the weight in any definite degree. During the time of parturition and also during the early part of lactation, the same was true, but as the lactation period advanced, the weight curve for the lot receiving calcium, cottonseed meal and South Park hay, and for the lot receiving calcium, phosphorous, cottonseed meal and South Park hay, ran above the other weight curve and showed a very interesting beneficial effect.

Not enough data have yet been compiled on the measurements of the lambs to draw any definite conclusions, but the few measurements which were made last year during the first year's work, lead us to believe that we will be able to show a larger diameter for the heart girth, and a larger diameter for the cannon bone when mineral is fed than when it is left out of the ration.

Sheep Summer Fallow (Akron)

Sheep have been carried on two standard dryland rotations and on native sod pasture for a series of years to determine their value on dryland farms. The practice has been successful in keeping down weeds on summer fallow and the sheep have been maintained satisfactorily on home-grown feeds.

Winter maintenance rations for ewes, including the common forage crops of the drylands, sweet clover and a protein concentrate, have been compared. A carrying-capacity test on native sod has also been carried. Enough data are now available on this work to furnish reliable information on the results that may be expected in carrying sheep on the average non-irrigated Eastern Colorado farm.

Utilization of Dryland Feeds

Non-irrigated Eastern Colorado produces a large portion of the state's grain crop. The carbonaceous grains and forage crops produced there offer opportunities for feeding livestock.

Hog millet is an important emergency crop for the dryland. Planted as late as July 1 when other crops have failed on account of hail or drouth, it will still mature a grain crop. The fattening value of the different grains available and especially hog millet when fed with carbonaceous roughage and supplemented with a protein concentrate, is a problem that has been worked upon this year.

Winter Hog-fattening Test.—Ground barley self-fed with protein and mineral mixture supplements showed 88.1 percent the feeding value of shelled corn in winter fattening tests. Hog millet showed 103 percent the feeding value of shelled corn in the same experiment. Protein and mineral supplements were reduced in increasing amounts

by the substitution of (1) barley for corn, (2) hog millet for corn and (3) a corn-and-hog-millet mixture for corn.

The palatability of grains fed ranged in the following order: Hog millet (ground), hog millet and corn, shelled corn and ground barley. Pigs fattened on hog millet showed a higher dressing percentage and a lower carcass shrinkage in the cooler than pigs fattened on corn or barley. The pork from millet-fed pigs was of excellent texture and flavor, both when cooked fresh and after curing.

Summer Hog-fattening Test.—Hogs were fattened on a succession of annual pastures including fall-sown rye, spring-sown barley and sudan grass with a self-fed grain and protein supplement. These hogs were finished for a late August market and produced very satisfactory gains. The grain supplement used was composed of ground barley and hog millet fed in separate compartments of a self-feeder. The greater palatability of the hog millet was demonstrated by the fact that the pigs consumed only about 17 percent barley.

Lamb-fattening Test.—Hog millet (ground) had 84 percent the feeding value of shelled corn when fed with cane hay and a protein supplement to fattening lambs. A protein supplement composed of ¼ pound of cottonseed meal and ¼ pound No. 2 alfalfa meal proved just as efficient and much cheaper than ½ pound of cottonseed meal when fed to both growing and fattening lambs.

According to these tests, well-balanced fattening and growing rations in non-irrigated sections of Colorado proved as cheap and efficient in non-irrigated sections as in irrigated sections of the state.

Hog Feeding in the San Luis Valley

A study of fattening rations for hogs pastured on field peas in the San Luis Valley is being made. Considerable inquiry as a result of poor gains and rather high death losses has prompted this line of investigation. Feeds used include field peas, barley, alfalfa meal, tankage, cull potatoes and skimmilk.

All-mash Feeding vs. Scratch-and-mash Feeding of Poultry

During the past year our work on comparing the results when feeding all-mash to laying pullets as against a mash-and-scratch ration did not give satisfactory results because colds and roup threw the groups out of condition. We, therefore, felt that it was necessary to carry on another season. On October 1 we placed two groups of pullets in a divided house. They are now being fed the two rations and records are being kept.

We are also working on a new problem of heating old kerosene lamp incubators by electricity. This work will be carried on until hatching season is completed.

Following is a list of the projects upon which we desire to prosecute work during the year:

1. Beet By-product Rations for Fattening Beef Calves (Purnell)
2. Ration Experiments with Cattle
3. Summer Cattle-fattening Experiment
4. Range Management
5. Cornfield Lamb Feeding
6. Ration Experiments with Lambs
7. Comparative Value of Different Kinds of Molasses in Lamb-fattening Rations (Purnell)
8. Winter Maintenance of Breeding Ewes
9. Utilization of Dryland Feeds (Akron)
    a. Winter Hog Feeding
    b. Summer Hog Feeding
    c. Winter Lamb Feeding
    d. Winter Maintenance of Ewes
10. Hog Feeding in San Luis Valley
11. All-mash Feeding vs. Scratch-and-mash Feeding of Poultry
12. Electric Heating of Small Kerosene Lamp Type Incubators

Recommendations

Our work in the Animal Investigations Section has been confined to a very limited part of our field; that of fattening meat-producing animals. We should take care in the immediate future of certain problems arising with regard to the feeding of dairy cows and the raising of dairy calves both in irrigated sections and dryland sections. We should also look some years ahead to financing experimental work in connection with dairy manufactures. There are problems now existing upon which we should be doing work but it is impossible for us to undertake it on our present budget.

Respectfully submitted,

GEO. E. MORTON

REPORT OF BACTERIOLOGIST

To the Director:

I have the honor to submit herewith the annual report of the Bacteriological Section of the Colorado Experiment Station for the year December 1, 1928 to November 30, 1929.

During the past year, we have directed our efforts along four lines of study as described briefly below. Three of our projects have been supported by the Purnell fund and one by the Adams, Hatch and State funds jointly.

The personnel of the section has changed somewhat since last year. Miss Laura C. Stewart, formerly a fellow on half time, has been made a full-time assistant; Robert Gardener has followed Justus C. Ward as soil chemist of the Rocky Ford Laboratory; Mrs. Mildred Brown Carpenter, a former member of the staff, has replaced Miss Ferguson, resigned; Miss Esther Elliott has succeeded Miss Ann Roberts as student laboratory assistant.

Projects

I. **Alfalfa Wilt—Purnell Fund.**—There is no more vital problem in the agriculture of Colorado than restoring our alfalfa fields to their former state of productiveness. The rather general decline of this crop which has been observed during the last 5 years appears to be due to two causes: Winter injury resulting from the planting of unhardy varieties, and the bacterial wilt, a root infection, which follows winter injury. The most practicable solution of this trouble lies in the discovery of varieties that are adapted to our winter conditions and which are also resistent to the wilt.

Two years ago and again this spring the Bacteriology Section and the Agronomy Section, cooperating, planted a number of variety-test plots in Boulder, Larimer and Weld counties. The list of varieties included Grimm, Cossack, Hardigan, Ladak, Canadian Variegated, Turkestan and Utah Common.

Excellent stands were secured with all plantings in 1929, with the exception of one plot in Weld county which was destroyed by grasshoppers. While the plots are still too young to yield significant results, there is some indication that Grimm and Canadian Variegated are superior to the others. Similar tests are to be made next year in Prowers county in cooperation with the Denver Alfalfa and Milling Products Company.

II. **Botulism Poisoning.—Adams and Hatch Funds.**—Hardly a year passes but one or more deaths result from eating either spoiled vegetables or meat that has been improperly canned. When we realize

that a human life is valued at $5000 and that last year there were three deaths in the state from botulism poisoning, a preventable disease, at a cost of $15,000 to the community, the importance of this investigation needs no argument.

We have completed over 6,000 tests for the purpose of determining how long a time and at what temperature it is necessary to heat the spores of the germ that causes botulism poisoning to kill them. The temperatures we have used correspond to the boiling point of water for all elevations ranging from the altitude of Rocky Ford to Cripple Creek, and the exposures from ½ hour to 8 hours. Our results indicate that there is no place in Colorado where vegetables and meat can be canned with absolute safety against this form of food poisoning unless the cans are heated at the temperature of boiling water for more than 6 hours which is wholly impracticable. Canning in the pressure cooker where temperatures above the boiling point of water can be obtained appears to be the solution of the problem.

Further experiments on the determination of the lag in canned peas and carrots have been made.

It is our plan to make a further study of the distribution of the germs of botulism poisoning in Colorado soils during the coming year.

III. Winogradsky Method of Testing Soil Deficiencies.—The value of this method in determining fertilizer needs and its importance to the agriculture of the state was set forth at some length in the semi-annual report of this section.

During this year we have compared this method with that of Neubauer, a chemical method, and find that a very close correlation exists. In our opinion the method is sufficiently reliable to warrant our recommending it as a routine procedure in testing soils for phosphate, potash and lime deficiencies. The Great Western Sugar Company, the Holly Sugar Company, The American Beet Sugar Company, The National Sugar Company and the Utah-Idaho Sugar Company have all been using the Winogradsky method the past season with excellent results. Just recently we have examined a number of soils for the Kuner-Empson Packing Company. The fact that these large industrial corporations place so much reliance in the test speaks well for the value of the method.

Our records show that we have examined soil from more than 200 farms during 1929 for fertilizer deficiencies. In general we can say that most of our soils would be improved by the addition of phosphate.

In order to check the reliability of the method, we carried on extensive fertilizer experiments with sugar beets on six different farms in Larimer county the past season. Two of these were located near

Wellington, one near Harmony, one east of Loveland and two near Berthoud. Our tests showed the soil on two of these farms to be deficient in phosphate but not in potash or lime. On each of the farms four different fertilizer treatments were used: Acid phosphate, at the rate of 200 pounds per acre, potassium sulfate 100 pounds per acre, acid phosphate 200 pounds and potassium sulphate 100 pounds, and a check to which nothing was added. At the end of the season, tonnage and percentage of sugar were determined for each treatment on each farm. The results showed an increase of 134 percent in tonnage on one farm where phosphate was added and 13.7 percent on another with a like deficiency and like treatment. Where our tests showed nothing lacking there was no benefit from the fertilizer.

The field work of this project has been under the immediate direction of Dr. D. W. Robertson of the agronomy section to whom much credit is due for the successful outcome of the experiment.

So far as I know our laboratory is the first one in the United States to perfect and put into use this bacteriological method of determining fertilizer needs, and if it is as valuable as it promises, it will be one of the greatest contributions to agriculture that has ever been made, for by it we shall be able to tell every farmer in Colorado what particular fertilizer his land requires to make it more productive, and this information can be available for his use in less than 1 week after he sends in the soil sample. I submit to you this question: What measure of farm relief can possibly benefit the farmer more than this?

IV. Rocky Ford Niter Investigation—Purnell Fund.—Investigations at the Rocky Ford Experimental Farm have been largely continuations of the previous year's work. The Bacteriological Section has been particularly concerned with the following lines:

1. The control of bacterial blight of beans by means of 2 and 3-year-old seed.

In the light of this season's results we question very seriously whether it is safe to plant diseased seed, even if it is 2 years old, with the hope of controlling blight.

2. Relation of blight, mosaic, wilt, nitrates and plant lice to cucumber failures.

Our experiments point rather conclusively to mosaic as the most important factor in cucumber failures in the Arkansas Valley, and to the melon aphis as the agent which carries the virus from the common milkweed to the cucumber plants.

3. The use of crop residues in reducing the accumulation of soil nitrates.

Experiments over a period of 3 years indicate that the amount of nitrate in a soil can be reduced appreciably by plowing under sawdust, straw or corn fodder. In view of these findings, these residues should be applied cautiously to a land already low in nitrate, but they can be used to advantage when nitrates threaten to become excessive. If funds will permit, it is our plan next year to utilize this information in the reclamation of certain lands in the Western Slope where the soil nitrates have become so concentrated that the soil is no longer productive.

4. Crop rotation experiments for the control of soil-nitrate accumulation.

A brief report by Mr. Gardener, chemist of the Rocky Ford Laboratory and Experimental farm follows:

"The general trends of nitrate production and accumulation in the cultivated soils of the Arkansas Valley were so well established by the laboratory prior to the present season that it seemed advisable to direct the continuation of the work toward a more quantitative measure of the effect of the contributing factors. As the station facilities, both in personnel and laboratory equipment, impose a definite limit to the volume of work which can be done, the more intensive attack made it necessary to narrow the scope of the work to fewer aspects of the subject. Consequently only two principal phases of the problem have received detail study this year—the two phases being the effect of crop residues and fertilizers on nitrates in fallow soil, and the effect of specific crops and crop rotations on the production and accumulation of nitrates.

"The procedure previously followed with the former of these phases was adopted without modification for the present season. Forty-six plots, including the 23 plots sampled last year, and a new series of 23 plots were sampled weekly for analysis. The five green-manure plots formerly studied were similarly sampled.

"The study of the effect of crops and crop rotations was modified to permit more intensive observation on fewer plots. The vine crop and new alfalfa with nurse crop on the 8-year rotation were selected for study. Samples were taken both of surface and sub-soil every other day in an attempt to get a quantitative measure of the total amount of nitrate produced, including the portion carried downward by the irrigation water. Samples of the irrigation water were taken daily to determine the amount of nitrogen which might be introduced by irrigation.

"Including the water samples, approximately 2500 samples have been analyzed since sampling began on April 1.

"Report cannot be made on the conclusions drawn from the season's work, as the work of analyzing and interpreting the accumulation of data has not been completed, but the general conclusions of previous years have been verified. That there is an invariable accumulation of nitrates in excess of utilization in the upper few inches of the soil growing cultivated crops during the season of maximum temperature, that this condition is less pronounced in uncultivated crops, and that the addition of green manure reduces the excess, are a few of the facts again definitely confirmed. It has been further confirmed that within the scope of the investigation any source of nitrogen found in the soil, except that introduced with fertilizers and crop residues or by fixation within the soil, is of negligible importance.

"Improved methods of farming, including more rotation in cropping, addition of more organic matter, better irrigation practices and improved drainage conditions are acting to reduce the importance of nitrates as a toxic factor in crop production. But the effect of abnormal amounts of nitric nitrogen and the excessive bacterial activity in the soil on the general problem of soil fertility are problems pressing for solution, and the fact of a condition existing where the nonsymbiotic fixation of nitrogen is in excess of the needs of crops makes the explanation of the factors involved in producing this condition a question of world-wide importance. With few exceptions the addition of more nitrogen to the soil than is accumulated in the ordinary cropping sequence is a universal need."

Respectfully submitted,
WALTER G. SACKETT, Bacteriologist.

REPORT OF THE BOTANICAL SECTION

To the Director:

The following is a report on the projects carried by the Botanical Section, December 1, 1928 to November 30, 1929:

Range and Pasture Improvement

1. **College Foothill Pasture, Fort Collins.**—Records continued of quadrats, growth, phenology and environmental factors in relation to the continuous and deferred-rotation systems of grazing.

2. **Laramie River Valley.**—Quadrat studies continued on the improvement of sagebrush range by burning.

3. **North Park.**—Experiment started in cooperation with extension service on the improvement of sagebrush range.

4. **Upper Foothills, 7,000 feet, Virginia Dale.**—Composition and abundance of the vegetation, reseeding abandoned plowed areas, growth habits, quadrat studies, environmental factors, readings, mapping —in relation to better range management and the range improvement.

5. **South Park.**—Much of the sheep loss in the park traced to **Triglochin maritima.** Data collected and recommendations given on range improvement and range management.

6. **Irrigated Pastures.**—Analysis of seeding mixtures and resulting stands. Quadrats studied on six pastures under various farm conditions. Many valuable data collected on the composition of the pastures in relation to grazing practice.

7. **Methods of Quadratting.**—Data have been gathered in an effort to devise quadratting methods adapted to range studies. The area-list method has proved especially valuable.

8. **Miscellaneous.**—A beginning has been made on studying the use made of various native species by sheep and by cattle. We do not know enough about this yet to ''size up'' ranges adequately.

Recommendations have been given to a number of stockmen on range utilization and reseeding.

Weed Control.—The work on weed control the past year has consisted chiefly of testing in the field various chemicals as weed killers. Previous work has shown that arsenical sprays do little but kill the tops of weeds under Colorado conditions. Emphasis this year was laid on testing chlorates.

During the first of the season Walter Ball, who was in charge of the work, accepted a position in charge of the weed control for California and B. J. Thornton took charge of the work here.

Weed plots were laid out in the Arkansas Valley, near Manzanola, in the San Luis valley 8 miles south of Alamosa and on the Western Slope 3 miles northwest of Grand Junction. These plots were sprayed with sodium chlorate and calcium chlorate and also treated with crystaline sodium and calcium chlorates. Several rates of treatment per acre were tested to get an idea of proper strength of the chemical to be used. Part of the plots were irrigated, the rest left dry. Untreated check plots were left adjoining. Also areas were treated with carbon disulfide as a further check.

The above-mentioned plots were chiefly bindweed but experiments were also tried on poverty weed, Russian knapweed, Canada thistle and white weed.

Local plots, to test the killing effect of chemicals, were also laid out at Wellington and Ft. Collins in Larimer county and also at two locations in Weld county and additional plots in Denver county.

All of these plots were extensive enough and properly planned so as to test the effect of the various strengths of the chemicals used and to show the influence of time of application, manner of application and irrigation, on chemical treatment of weeds.

Three trips were made to each of the plots during the season to make treatments and observations. The results of the 1928 tests indicate that the effects of chemical treatment with chlorates are frequently most evident the spring following the previous year's treating.

In some instances excellent results were obtained from use of sprays. Conditions, such as time and method of application, irrigation and weather, appear to play an important part in the success of chemical weed treatments. No definite conclusions can as yet be arrived at.

In addition to field tests, greenhouses and laboratory experiments are being conducted by Mr. Cation on the physiological reaction of chlorates on plants.

Cereal Diseases.—Intensive study has been made of the physiology of **Tilletia laevis** causing stinking smut of wheat. Mr. Henderson returned from Ames in June to complete the write-up of his studies formerly carried on here. Mr. Bodine is continuing the study which he started last year and is writing up his results.

Truck-crop Disease Studies.—The work the past year on truck-crop diseases has centered around the study of onion diseases, particularly those in storage.

The increased onion acreage in the Arkansas valley the past year has resulted in increased trouble from diseases. In June, Mr. LeClerg established a field laboratory at Rocky Ford working out from that point as a base.

His studies and observations are as follows:

"**Pink Root.**—This new disease was first found in the state near Littleton in 1928. This past season it has been found in isolated fields near Canon City and around Rocky Ford. The disease in some cases caused a complete loss. It was apparently introduced into the state on Bermuda sets from Texas. Circular 57, "Pink Root of Onions," was published January, 1929, describing the disease and recommending control measures.

"**Purple Blotch.**—This disease was found the past season in severe form around Rocky Ford. In one field an estimated loss of

10,000 pounds per acre resulted. The disease is of fungus origin and directly follows continued growing of onions. Sanitation and rotation will keep the disease in check.

"Fusarium bulb rot was also found in two fields near Rocky Ford."

Neck Rot.—Observations were made on this disease thruout the valley. Mr. LeClerg has made a study of storage conditions affecting onions conducive to neck rot. Some of the results of this study are published in bulletin 301-A.

Thruout this season observations and notes were made on various other diseases of crops in the valley. A comprehensive report on this has been turned in to the director and also sent to the Office of Plant Disease Survey, Washington, D. C.

Report of the Seed Laboratory for 6 Months Ending December 1, 1929

Samples Tested.—	Current Samples	180
	Referee Samples A. O. S. A. N. A.	10
	International Seed Testing Congress	15
	Investigational	30
		235

Most seeds are dormant at this time of year so the total germination tests made is 735.

Investigational—Dormancy in Wild Oats and False Wild Oats.—Thirty samples of wild oats were obtained from several western states. Threshing of these and germination tests of all samples have been made. Counts are now ready for later additional tests in regard to dormancy.

In connection with a study as to the possibility of detecting mixtures of **Melilotus alba** and **officinalis,** detailed microscopic examinations have been made of 27 samples of hand-threshed sweet-clover seed. The seed has been secured from various parts of Colorado and from other states. More samples are on hand and are being examined as time permits.

Three months' training have now been given a student in order to have additional help for the busy season which will probably begin about December 15. Arrangements have also been made by which Miss Lyon will return to the laboratory for the busy season, January 1 to June 1, 1930.

New Equipment Installed.—

1 blower
1 seed-counting equipment
1 balance for large samples
1 Marchant calculator
4 new table tops.
2 germinators

During the time, May 27 to June 25, Miss Lute made a study trip visiting several of the most important seed laboratories in North America. Her report in brief is as follows:

"I spent 3 days at the Virginia Seed Laboratory. Virginia enforces its seed law more satisfactorily than any other state. A study of their plans and procedure in law enforcement has given me numerous ideas for the enforcement of our law with the increased appropriation which we are pledged to use for that purpose.

The Virginia laboratory had recently installed new equipment and was adapting uniform laboratory practice to special seeds and conditions.

June 3, 4 and 5 were spent in a meeting of the executive committee of the Association of Official Seed Analysts of North America. The enforcement of seed laws must be based upon the use of similar methods, and a uniform interpretation of results secured in seed testing. At this meeting plans were made for various cooperative projects looking toward unifying results from all laboratories. The results of this work are to form a part of our program at the coming meeting in Des Moines. I am chairman of the committee on cooperation between laboratories.

The following 4 weeks were spent working in the seed laboratory of the United States Department of Agriculture.

This laboratory has experts and investigators in all lines of seed work. I was able to carry on special work under Mr. Hillman on the various species of bent grass and the various species of Brassica. Dr. Toole and Mr. Goss gave me much time and opportunity to study germination methods in chambers and greenhouses and the interpretation of results obtained. Miss Sirrine, who has charge of all purity testing, assisted me to familiarize myself with all the latest knowledge in that field.

The problem I am investigating in connection with wild oats involves a study of the chromosomes of wild oats and false wild oats. While in Washington I was able to familiarize myself with the methods used by Dr. Langley in the study of chromosomes so that next spring I hope to be able to finish this problem.

Several days were spent in the Maryland laboratory. This laboratory has very fine equipment of all kinds, expertly installed.

The New York laboratory is organized and equipped differently than any other seed laboratory and gave special help in simplicity of keeping records and reporting results of tests.

It was possible to make a trip from Buffalo to Toronto and spend July 4, which is not a holiday in Canada, studying the work

there. The Canadian laboratories work under a seed-grading system which they feel is better than the American systems of labelling exact quality.

The Wisconsin laboratory ranks next to Virginia in efficiency of enforcement of the state seed law. The time spent there was taken up largely in discussing methods and plans for law enforcement.

The Northrup King and Company in Minneapolis furnished excellent opportunity to study testing of vegetable seeds on a large scale.''

Cooperative Work.—Cooperative relations have been continued during the past year with the United States Department of Agriculture on barberry eradication.

The Office of Sugar Crops and Diseases established a laboratory in association with the Botanical Section during the past year. Dr. Stewart and Charles Lavis are located here studying the problems of beet disease and breeding for resistant varieties.

Publications of the Botanical Staff for 1929

Durrell, L. W. A new Pathology Text (review)
Principles of Plant Pathology by Charles E. Owens.
Phytopath. 19:177.

Hanson, Herbert C. Range Resources of the San Luis Valley.
Colo. Sta. Bul. 335:1-60.

________ Grazing Types in Colorado.
The Cattleman 15:57-63 (April)

________ Reseeding Waste Range Land.
The Cattleman 15:31 (May)

________ Intensity of Grazing in Relation to Proximity to Isolation Transects.
Ecology 10:343-346.

________ Analysis of Seeding Mixtures and Resulting Stands in Irrigated Pastures of Northern Colorado.
Journ. Am. Soc. Agronomy 21:650-659.

________ Discussion on "Eradication of Brush and Weeds from Pastures" by A. E. Aldous.
Journ. Am. Soc. Agronomy. 21:666.

________ Pasture Plants for Sheep.
American Sheep Breeder, July.

LeClerg, E. L. Some Common Diseases of Ornamental Plants.
Colo. Sta. Bul. 351.

________ Neck Rot of Onions.
Colo. Agr. Exp. Sta. Bul. 301-A.

Rogers, Charles F. Canada Thistle and Russian Knapweed and Their Control. Colo. Agr. Exp. Sta. Bul. 348.

________ Zygophyllum fabago in Colorado. Science.

E. C. Smith. Trametes hispida—A Destructive Parasite in Apple Orchards. Mycologia.

________ Some Phases of Spore Germination of Myxomycetes. Am. Jour. Bot., Nov. 1929.

________ Longevity of Spores of Myxomycetes. Mycologia, November, 1929.

Charles F. Rogers and Ira Hatfield. Carbon Disulfide for the Eradication of Perennial Weeds. Colo. Agr. Exp. Sta. Bul. 347.

LeClerg, E. L. Pink Root of Onions. Colo. Agr. Ext. Cir. 57.

Herbert C. Hanson with F. E. Clements and J. E. Weaver. Plant Competition. Carnegie Institution Publication (Text).

Hanson, Herbert C. The Struggle for Existence Among Range Plants. The Producer, 11:57.

________ Reseeding Range Lands. The National Wool Grower, October, 1929.

Publications Submitted or in Press

E. C. Smith. Ecological Observations on Colorado Myxomycetes.

E. L. LeClerg. Cultural Studies of Some Soil Fungi.

Ira Hatfield and Charles F. Rogers. Formula and Apparatus for Measuring the Liquid to Gas Volume Change.

Charles F. Rogers and Ira Hatfield. A Chemical Indicator for Testing in the Field the Diffusion of Carbon Disulfide Gas thru the Soil.

________ Root Systems of Wild Morning Glory and Poverty Weed Regeneration Studies.

H. C. Hanson. The New York Symposium on Pasture Management. The Breeder's Gazette.

________ Legumes for the Tame Pasture.

________ Improvement of Sagebrush Range in Colorado. Colo. Agr. Exp. Sta. Press Bulletin.

________ Range Reseeding. The Producer.

Respectfully submitted,

L. W. DURRELL, Botanist.

REPORT OF THE CHEMIST

To the Director:

During the past 12 months this section has finished the project designated "effects of clover and alfalfa in rotation; carbon dioxid in the soil." The results have been presented in four parts, one of which has been published as Bulletin 319. The main features of the results were that we did not find any significant increase in the total nitrogen in the soil, and the nitric nitrogen was contiuously very low.

The carbonic acid in the soil atmosphere was maintained at very much larger quantities under these crops than in fallow land. The soil complex in the soil experimented with corresponded to 13 hydrogen atoms and was not affected by the crops.

The water-soluble potassium was quite abundant in the soil and varied in different portions of the plot, but in all cases was greatly increased by the growing crops. There is in this soil a large quantity of potassium that forms no part of the soil complex. The variation in the water-soluble phosphoric acid was not followed.

Supplemental to the main project, small plots of wheat were grown on the land after the crops had been plowed under during the preceding fall. A part of the fallow plot used had been planted to corn. This is how we came to have three crops and a fallow in this experiment; the crops were clover, alfalfa and corn with a fallow.

The wheat yield was the largest after fallow and smallest after alfalfa, the difference being 18 bushels per acre. The protein content was highest after alfalfa and lowest after corn. After alfalfa it was 19 percent; after corn 12.25 percent; after clover, 17.5 percent, and after fallow, 17.25 percent.

This wheat experiment was repeated using the whole plot of land. This year the differences of the preceding season had largely disappeared and the general effects seemed to be those of fallowing. The various plots yielded around 55 bushels per acre. We do not wish to prosecute this work further.

The only active project now being prosecuted is a study of the extent and character of the changes effected in alfalfa hay by weathering or injury by rain in the field. This is really an extension of work done 32 or 33 years ago, so far as the analytical features are involved, but this work is being supplemented by biological work in feeding rats. It may require longer to complete this work than we originally anticipated, but the results so far promise to be of considerable interest. They confirm and explain observations previously made. It may be safe to state at this time that the vitamins of alfalfa hay are quite easily soluble, so the loss in this respect is very large.

Respectfully submitted,
WM. P. HEADDEN, Chemist.

REPORT OF THE ENTOMOLOGICAL SECTION

To the Director:

The following is my annual report upon the work carried in the Entomological Section of the Colorado Experiment Station during the 12-month period just closing.

The Entomological Section has carried 10 active projects upon all of which some work has been done. These projects are listed below with brief comments upon the work done in each.

The investigational work is so coordinated with teaching and the regulatory work under the state entomologist, as to give the section part-time service of 10 people. Two of the projects deal with rodents and are zoological rather than entomological in nature.

The insect injuries to crops during the past year have been serious at times, but on the whole, the losses have not been unusual. Better control methods are continually being used by the growers of farm, fruit and vegetable crops in the state which offset the occasional introduction of a new pest and the enlarged area in which these crops are grown.

Projects of the Year

Plant-louse Investigations.—This project is carried chiefly on Adams and Hatch funds. The work is rather technical in nature and is carried by Miss M. A. Palmer and the writer. Two technical papers have been published on this work during the year in which host plants, life histories and descriptions of new species have been given. These papers were published in Annals of the Entomological Society of America. An annotated list of Colorado Aphidae, upon which we have been working for some time, has made considerable progress.

Ants in Relation to Plant Lice.—Dr. C. R. Jones is in charge of this project. It is supported on the Hatch fund. This is also a technical study for the most part, but includes methods of control. Bulletin 341, Ants and their Relation to Aphids, published during the year, gives the results of a large portion of this work. It is condensed from a rather lengthy thesis written for the Ph.D. degree in the Department of Entomology, Iowa State College.

Codling-moth Studies.—The codling-moth, which has proved to be so difficult to control in the Colorado Valley in this state, has called for continuous work because of its changing habits, which also call for more refined methods for control which are not yet altogether satisfactory in parts of Mesa County. Good control is secured in other sections of the state where our recommendations have been followed.

This project is being carried under the direction of George M. List and J. H. Newton, with the assistance of Louis Davis.

Codling-moth Control by Means of an Egg Parasite.—This investigation is rather a unique one and has called for a great amount of ingenuity to meet the unexpected difficulties that have arisen in the work. The project started off with great promise, when suddenly we became aware of the presence of two mites, one, **Pediculoides** sp., attacking the Angoumois grain moths used in the experiment, and another, a Gamasid, attacking the eggs of the moth upon which the parasites were being reared. These mites were about to ruin the experiment when Mr. List succeeded in controlling them with flowers of sulphur. Following this, the parasites refused to ovaposit in the eggs, which we believed to be due to the sulphur in the breeding cages. This difficulty seems now to be overcome, and at this writing all promises well again for the work.

Grasshopper Control.—The work on this project has been in charge of Frank C. Cowan as deputy state entomologist, and has been directed against the Mormon cricket (**Anabrus simplex**) which is a wingless grasshopper. This insect has been quite destructive to the crops, especially of the new settlers in Northwestern Colorado, for a number of years. The work has been in collaboration with the Bureau of Entomology of the U. S. Department of Agriculture and has been supported upon special appropriation by congress and the budget of the state entomologist. Mr. Cowan reports most satisfactory results from his work of the past year. It seems probable that by next July this insect will be practically exterminated for many years to come in Moffat and Routt counties of this state. A bulletin manuscript giving the results of the work done on this project by Mr. George Langford is in the hands of the printer.

Potato Flea-beetle.—Bulletin 337 gives the results of this work up to a year ago. The past year the work has been carried further by Leslie B. Daniels, who has added materially to our knowledge of the habits of this very destructive insect and the methods that may be used for its control.

Resistance of Bees to Foul Brood.—This is a new project in charge of R. G. Richmond, deputy bee inspector for Colorado, upon which considerable work has been done the past year.

Colorado Insect Fauna.—This is a continuing project in charge of Sam McCampbell. It has for its purpose to get together as full a collection of Colorado insect fauna as possible, with notes on food plants, the hosts, dates of collection, name of collector and other im-

portant information. It also includes the determination of material collected and the making of exchanges with other entomologists in this and in foreign countries. Good progress has been made during the year.

General Insect Investigations.—This project is carried from year to year to enable this section to do emergency work on short notice whenever any insect outbreak occurs within the state. Some work on this project is called for practically every year.

Rodent Life Habits.—W. L. Burnett is in charge of this project which has been undertaken to obtain more definite information concerning the life habits of some of our most destructive rodents in order that methods of control may be made more efficient. Good progress has been made this past year.

Rodent Poisoning.—This project is closely correlated with the preceding, under the direction of Mr. Burnett. Its purpose is to improve present methods of rodent control by means of food poisons.

The insect collection and the entomological laboratory are being moved into the new fireproof building constructed in connection with the building which houses the department of zoology and entomology. This building will be greatly appreciated in our work. We shall have a feeling of security now, as the danger of losing our insect collection by fire is made very small.

Respectfully submitted,
C. P. GILLETTE, Head of Entomology Section.

REPORT OF THE AGRICULTURAL ECONOMIST

To the Director:

During the year ending November 30, 1929, the Section of Economics and Sociology has given attention to the study of nine projects, eight of which have been approved for development with Purnell funds.

Project No. 1.—During the year 1926-27 the Division of Farm Management and Costs, Bureau of Agricultural Economics, U. S. D. A., conducted an extensive fruit survey which was nation wide in scope. In this study certain districts of the western slope were included. Subsequently this work was expanded by the Extension Service and the Department of Economics and Sociology of this institution. For three successive seasons the members of the staff, in this department in cooperation with the Extension Service, have visited

farmers in Mesa, Delta, Montrose and San Miguel counties, and have secured data relative to the acreage and production of farm crops, together with the disposal of these crops; also information pertaining to numbers, values, production, purchases and sales of livestock; an itemized list of farm receipts and farm expenses; estimates relative to the value of food raised on the farm for home consumption; and investment in real estate, livestock, machinery and feed. Each individual record has been summarized and returned to these men. In additon, a preliminary report covering the major features of the survey has been taken back to cooperating farmers each year. A special report covering the 3-year period is in preparation and will be published in due time.

Project No. 2.—Detailed accounting records have been obtained from several farmers in the Greeley area and for some of these units the study has been continued for the eighth year. Financial records have been secured from several farms in the same general region. For the northeastern section of Colorado the work is in its third year.

At the beginning of the year 1929 a few representative dairy farms in Weld and Larimer counties were included in the project with the object of investigating the status of the dairy enterprise as it is being developed on these irrigated farms. The entire group of farms in this project has been selected for the purpose of providing a continuous record of economic changes in this area and in order to determine the relative profitableness of the different types of farming which are representative of the region.

Colorado station bulletin No. 353 entitled "The Cost of Producing Crops on Irrigated Farms" has been published and distributed during the year. A manuscript is practically completed relating to cattle-feeding and lamb-feeding costs and returns covering a 7-year period.

Project No. 3.—In our reorganization of this study contacts have been established with 19 North Park cattlemen who have agreed to cooperate in the matter of keeping the necessary records. Complete inventories have been obtained on each of these ranches as of January 1, 1929. An average of five visits has been made to each ranch during the year for the purpose of getting acquainted with management practices and to inspect and check the records which these men are keeping.

During the summer a survey was made of the feeder cattle to be marketed during the fall months. At that time approximately 25 of the ranches in addition to those cooperating in keeping ranch records, provided information in regard to their feeder cattle. These data were summarized and distributed to interested parties during the

early autumn. Special data have also been collected on the labor requirements involved in cutting and putting up hay in the North Park area. It is our purpose to issue a preliminary report on the latter phase of this project so that ranchmen in this general area may be in a position to check their work with the records which have been compiled.

Project No. 4.—In our analysis of the social status of the Spanish-speaking people of rural Colorado, information has been assembled with respect to the economic, religious, social and educational conditions under which these people have lived in previous years. An attempt has been made to study the habits and life practices of the members of this group. Records have been taken regarding citizenship ideas and the present situation in Old Mexico which has led in many cases to immigration to the United States. Several typical regions have been visited during the present year and additional records have been assembled with the idea of making our report on this project more complete.

Project No. 5.—An intensive study has been made of county revenues and public expenditures in Larimer County and a manuscript giving the details of this investigation has been completed. Prior to publication this outline will be reviewed by the Division of Finance in the Bureau of Agricultural Economics, Washington, D. C.; also by individuals who have cooperated in supplying the information.

During the year Colorado station bulletin No. 355 entitled "An Outline of Colorado Tax Laws for Farmers and Ranchmen" has been published and distributed.

Another manuscript relating to the cost of operating schools in Larimer County is in preparation. An analysis of receipts and expenditures for educational purposes in 10 typical counties in Colorado is now in progress. Most of the statistical tabulations have been completed.

Project No. 6.—In April, 1929, farm business-analysis records were secured from a representative group of farm operators in the San Luis Valley. Substantially all of these operators have furnished information regarding the storage and marketing of the potato crop on their farms. Three years' work has been completed on this project and the results of this investigation are being compiled for publication at an early date.

Project No. 7.—A farm organization survey was conducted in the apple districts on the western slope during the month of May and some 80 or more records were obtained from farm operators who had previously given information for their farm business in 1927. Our

purpose in this study was to compare the results on farms where the major attention was directed to apple production with other types of farming in which other enterprises constituted an important part of the system. The records which have been assembled to date appear to indicate that farmers who rely upon apples as their chief source of income are not making as good returns as farmers who combine crop production with one or more classes of livestock.

Project No. 8.—In the summer of 1927 the Colorado Agricultural College, in cooperation with the Division of Land Economics, U. S. D. A., began a study of land utilization in Northwestern Colorado and farm business-analysis records for the year 1926 were secured from representative operators in Moffat, Routt and Grand counties. This study has been continued for 3 successive years. Information has been assembled relating to the area, production and sale of crops; the number, value and purchase of livestock. Miscellaneous income and all items of expense were secured for each farm each year. Some were crop farms, some livestock ranches, while others had no one outstanding source of income. Some farmers operated their farms part of the year and worked out the rest of the year in order to increase their incomes.

It would seem from our review of the more successful farms in this group that where there is sufficient area and livestock and where an attempt is made to keep down expenses, a man has a fair chance to succeed in this region. On the whole, livestock farming appears to offer the best chance for profitable returns, altho farms giving major attention to wheat and potato production did well in Moffat County.

Project No. 9.—During the past year the work in this field has been expanded until there is now available more or less information relating to the business of 80 Colorado cooperatives. These data have been assembled by personal interviews with men in charge of cooperative organizations and thru contacts with managers and individual farm operators who have been, or who are now connected with cooperative associations. The present available list includes: 22 elevators, 14 potato associations, 6 fruit associations, 4 cooperative creameries, 5 livestock associations, 9 central exchanges and 20 miscellaneous organizations. The miscellaneous group includes vegetable, honey, coal, turkey and oil associations, as well as cooperative stores

Information pertaining to a small percentage of the organizations is somewhat incomplete. This is due to encountering some opposition because of misundertanding concerning the motive behind the investigation. In some cases the present manager had been with the organi-

zation a relatively short period of time and he was therefore unable to furnish much information. These records will be summarized as promptly as possible and the material will be incorporated in bulletin form for distribution.

Respectfully submitted.

L. A. MOORHOUSE, Head of Economics Section.

REPORT OF HOME ECONOMICS SECTION

To the Director:

From this section of the station the report is necessarily brief, for the reason that not until early in the summer was it possible to secure a worker adequately trained in the physical and mathematical sciences.

The project underway is the baking of flour mixtures at high altitudes, part II. In this part II of the project it is the purpose to interpret from a physical-chemical standpoint the results obtained in part I.

Miss Florence Schott, appointed to carry on this research, reported for duty July 1. Miss Margaret Scheve entered upon her duties as laboratory assistant on the same date.

During July the time of both workers was spent in acquainting themselves with the problem and with the facilities for the research work to be undertaken. This involved much reading and correspondence.

Preliminary baking experiments in the altitude laboratory occupied a part of the month of August. These experiments demonstrated that accurate physical-chemical measurements on cake batters could not be made in a laboratory in which there was so great a fluctuation in temperature as was shown in the pressure chamber.

In addition to the study of temperature changes and the plotting of these on graph paper, much time was spent in studying the wattage of the oven and of the heat radiated, this, in order to find out to what extent the air in the pressure chamber would need to be heated or refrigerated for constant temperature.

During the past year Professor J. H. Scofield of the Mechanical Engineering Department did considerable work on the altitude laboratory. This work included a general overhauling and necessary repairs and adjustments to the motor, blower, pressure regulator, safety valves, etc. Also an extensive study was made on the effects of weather upon the laboratory temperature when running at various pressure, and various designs for insulation were worked out. The

insulation has also been installed. Steam heat was added to the outer machine room. Study and correspondence were carried on in an effort to find a way to control heating and refrigerating devices which will control the temperature to within 1°F. in the laboratory with a blast of air entering at all times ranging from — 20° to + 100° F. Another series of tests were run at all altitudes and all speeds of the motor and various pressures recorded which will permit thermodynamic calculations to determine the correct blower speed for each altitude.

In the interval during which the work of insulation was going forward, preliminary experiments and the assembling of apparatus has occupied the time of both workers.

Early in the summer the courtesy of the altitude laboratory was extended to Earl Working, of the Milling Department of the Kansas State Agricultural College for experimental work on his project on bread-making.

Respectfully submitted,

INGA M. K. ALLISON, Head of Home Economics Section.

REPORT OF THE HORTICULTURIST

To the Director:

I beg to submit herewith a brief report on the various projects carried by the Horticultural Section during the past year.

Onion Projects

1. **Cultural Projects.**—The improtance of the onion industry in the state is well recognized. With the rapid growth of the Valencia onion industry, particularly in the Rocky Ford section, the department has undertaken to study the comparative yield and cost of growing the Valencia onion from field-sown seed and from transplanted seedlings grown in the cold-frames or greenhouse.

In Northern Colorado the season is too short for the development of a maximum crop of Valencia onions from field-sown seed and the transplanting method has proved the most successful. This work at Fort Collins has been carried on for four seasons and during three seasons records have been kept of the yield from transplants. In 1927 the yield was 1250 some odd bushels. In 1928 the yield was 1541 bushels and 16 pounds. In 1929 the yield was 1235 bushels. This is reckoned on 52 pounds to the bushel. The yield for 1928 was remarkable but the season was very favorable for the development of the crop and one would naturally not expect yields of this size every

year. However, on the whole, the yields are very high and the transplanting method for the Valencia onion should prove profitable to this part of the state.

At Rocky Ford, from incomplete figures, there was very little difference in the transplanted onions and the field-sown onions; in fact, not enough to warrant the extra cost of growing the seedlings and transplanting. However, this first year's trial is no criterion, since the plants for transplanting were grown at Fort Collins and had to be shipped to Rocky Ford, resulting in a considerable loss in planting. Secondly, the season being 3 or 4 weeks earlier so far as onions are concerned, they were not planted until after the field-sown onions were planted, so that there was little advantage in the length of the growing season. Another year we plan to grow the plants at Rocky Ford and to have them in condition so that there will be an advantage in the length of the growing season for the transplants. We can then get a better comparison than from our first year's operation.

The cost per acre of growing the onions by these different methods according to figures kept at Rocky Ford, was $176.86 for the transplants and $108.93 for the field-sown onions. This difference as given would not hold good under proper conditions, as $20.00 of the $176.86 was the cost of replanting, which would not have occurred had conditions been right. A figure of $150.00 per acre as a cost for growing transplanted onions should be about correct. However, cost in onion growing is only relative. So much depends upon the character of the land and its conditions. A weedy piece of land would, of course, cost more, while the cost would be considerably reduced on very clean land. However, there is probably a difference of one-third in the cost of the two methods and this difference must be made up in heavier yields, otherwise transplanting in the Rocky Ford section would not be profitable.

2. **Variety Tests.**—There has been a considerable amount of complaint about onion seeds as obtained from various sources, and there was an urgent demand for a thoro test of seed and strains of seed as obtained from different seed houses. The results of these tests are very interesting. They are discussed and tabulated in the report of Mr. Allen, who was in charge of the onion work at Rocky Ford, and a copy of his report is attached herewith. It is very apparent that the present method of buying seed indiscriminately is a very serious one and has much to do with low yields and poor quality. This work has been of special interest to growers in the valley, and from their expressions during those visits, we are sure that the lesson has been a a good one.

3. **Onion-Seed Breeding and Selection.**—This phase of our onion work is progressing very satisfactorily. It is being carried on at Fort Collins. The first part of this project consisted in developing by selection a desirable type of Valencia onion so that we would have a pure strain of a desirable type. The second part of this program is to cross this type obtained as above with the Brown Australian onion. This onion is noted for its keeping quality. It has a hard, thick, brown skin, a color that is very desirable in the trade, but its yield is unsatisfactory and it does not seem to be adapted to our climatic conditions. It is now grown almost exclusively in California. We believe that if the yielding and eating qualities of the Valencia onion can be combined with the keeping qualities of the Brown Australian, we shall have an ideal onion for Colorado.

Considerable progress has been made in developing pure strains of the Valencia. It remains, however, to be seen whether the type selected will remain permanent or whether type is a variable factor that changes from season to season. Some very interesting results have been obtained from this work, but it is not ready for a report, since we have not been able to tabulate all the data in connection with this project.

4. **Onion Storage.**—The heavy losses in the storage of onions during the past season made it necessary to investigate the problems associated therewith. The following factors were considered: The effect of varying length of field curing prior to storage and state of maturity of the bulbs at harvest; the effect of close topping versus long topping, and effect of careful sorting to eliminate disease; moisture and temperature conditions in storage.

An adobe storage house was built, divided into two compartments and suitable self-registering instruments were installed. It is hoped that this project will give valuable data regarding the factors causing present losses in onion storage.

Head-Lettuce Projects

1. **Development of Tipburn-resistant Varieties of Head Lettuce.**—This work has been in progress at Fort Collins for the past 3 years and we have several crosses between the New York head lettuce and the small purple-tipped Mignonette head lettuce. The latter variety is resistant to tipburn but is too small for commercial planting. As would be expected, the cross breeds show various degrees of resistance and color. Some excellent heads or crosses were obtained and these have been isolated for further selection. This kind of work is necessarily slow and often disappointing, but we believe there is great possibility connected with it and the work will be continued.

2. **Fertilizer Work on Head Lettuce.**—The fertilizer work on head lettuce has given negative results indicating that the ordinary garden soil is not materially benefited from the use of commercial fertilizers and for the present we are convinced that the use of barnyard manure with crop rotation is the best and most economical method of maintaining or increasing production. We desire to drop this project from our program for the present, as there is other work more important.

3. **Irrigation.**—For 2 years we did considerable work with the use of water in head-lettuce growing. This whole subject of irrigation is possibly the most baffling of all the cultural practices used in the growing of the crop. No formula can be given for irrigation. There are, however, periods in the growth of the plant when the use of water may be very injurious to the crop. This is particularly true at the final stage of growth after the plant is headed but the heads have not hardened. If heavy irrigation is given at this time, the results have invariably proved fatal, especially during bright, relatively warm weather. Seed stocks develop rapidly and the plant is soon unsaleable. Different types of soils require different amounts of water and different temperatures and humidity call for different amounts or numbers of applications of water, so that it is impossible and impracticable to state how many irrigations should be given a crop of lettuce. Head-lettuce growing under irrigation is not only a science, but a fine art, and the average farmer has to learn by experience and observation how to use water properly.

Garden Pod Bean Projects

Under this project is included the work connected with the seed certification and naturally the bean projects are very closely connected.

1. **Variety Testing.** During the past season we had planted and under observation 175 varieties and strains of garden beans. A large percentage of these were from Germany, France, England and Canada, besides all available varieties and strains grown in the United States. In this work we are principally interested in developing varieties or strains for the canning industry and for vegetable growers in different parts of the country.

At present there is a great deal of confusion in naming varieties, for duplications and interchange of names are frequent. Our first task is to get pure and disease-free strains from these varieties to use as foundation stock for the work of seed certification. The importance of this work has been pointed out in previous reports.

Among the foreign varieties under observation there are some very promising ones, particularly from England. These would be superior to any of our own home-grown varieties, were it not for the stringiness of the pod which makes them undesirable to the consumer. We hope to be able to make selections from these desirable types and eliminate stringiness from them. This, of course, will necessitate several season's work and the growing of a considerable number of plants.

2. **Selection.**—With the beginning of the coming season we shall start a systematic selection from the best varieties and use these as foundation for wider testing and ultimate distribution among the growers. In connection with this selection, the disease question will be taken up and disease resistance stressed in making the selections. Bacterial blight has been one of the most destructive bean diseases that have occurred in the state and work for the control of this disease has been started.

We were fortunate during the past season in finding a 3-acre field badly infected with bacterial wilt. The whole field was completely destroyed with the exception of 50 to 70 plants that were found scattered over the field and unaffected by the disease. We harvested these plants and are going to use them as a foundation stock for strain selection, with reference to freedom from this particular disease.

3. **Foundation Stock.—(Seed Certification).**—With the development of a seed-certification program it is necessary to develop a reliable seed supply from which the growers may obtain their seed stock for the growing of certified seed. This work of developing foundation stock entails considerable work in the way of roguing for undesirable types and off varieties so as to obtain a pure line that is reasonably free from diseases of all kinds. The limited acreage at our disposal made it impossible to plant our own stock in large quantities. Our supply of seed stock of the most important varieties will possibly amount to 5000 or 6000 pounds. This seed stock is not all that we desired it to be, but it is a beginning and with improvements, that is, by careful roguing in the field during inspections, I believe that the seed will be far superior to anything in the market. Meanwhile, we should make every effort to develop superior strains to replace those that we now have ready. The work must be one of continuous progression and improvement. Further, there should always be original seed stock available, as the old seed stock in the hands of the average grower soon deteriorates and should be discarded.

Garden Pea Project

This project has been active for the past 3 years. Our chief interest is in the development of improved varieties suited for the

production of pod peas in the mountains. We have been fairly successful in this work and are now growing as much as 10 acres of pea seed of this improved variety. The seed is sold to vegetable growers and the demand has always been greater than the supply. This work will be continued. Besides the work of selection as indicated above, we have about 50 new varieties under observation. Several of these are of the canning type. It is possible that some superior varieties will be obtained from this testing and selection work.

Orchard Management

This project is carried at Austin. The results have been valuable to the growers. The best cover crops for apples are yellow-blossom sweet-clover and red clover for a two-season crop, while winter rye has proved best for peaches and one-season cover crop for apples. Hubam clover gives great promise as an annual cover crop but it is often difficult to obtain a stand.

European-Grape Project

We now have about three-fourths of an acre planted to the European grapes. Varieties like Tokay, Malaga, Thompson Seedless and Muscat have done well and are producing fair crops. All the European varieties require winter protection at Austin. The canes have to be taken down and covered with earth each fall and uncovered and tied up in the spring. This entails considerable work. We feel that these grapes can be successfully grown in many places on the Western Slope, at least to the extent of supplying the local and even the state market. As an extensive commercial crop it would come in direct competition with California and Arizona and this competition would be hard to overcome. However, for our own market grape growing has considerable possibilities.

The native grapes do exceedingly well and all varieties can be grown without winter protection. Considerable planting of this type of grape has been made.

General variety testing of fruits at Austin is in progress, especially with several sports of the Delicious and Rome varieties. These give great promise and will in the near future replace the old varieties. It is the intention not to give these sports new names, but to retain the old, since the chief difference is in the color and general attraction of the fruit.

Small-Fruit Projects

These projects are in care of Professor Lott and his report is attached. There are also attached reports by Professor Binkley.

Fruit Farm at Austin

The general situation in fruit production is very much the condition in farming. Specialization has developed to a remarkable degree

tho there are many indications of a change. Exclusive apple growing or exclusive peach growing is a very risky proposition in most of our fruit-growing sections, since there is only one source of income. It is just as easy to diversify in fruit growing as in farming, and to make fruit growing safe and profitable the growers should grow a number of fruits. Diversification does not necessarily mean large acreage. It can be done on small tracts with better labor distribution and with greater safety in income.

Primarily the fruit farm was bought to demonstrate how fruit growing should be done under proper methods of management and cultural practices. In addition, it was believed that all kinds of fruits that the soil and climate would permit should be grown. At the same time, we did not want to make the farm a fruit museum and a variety-testing farm. When the farm was purchased it was in a run-down condition. The land was impoverished and the trees neglected. The work of reconstruction has been accomplished and we believe that we have a model fruit farm. The following fruits are now being grown: Apples, 12 acres; peaches, 3½ acres; pears, 1½ acres; cherries, 1½ acres; plums, 1 acre; apricots, ½ acre; grapes, 1½ acres; miscellaneous fruits, 1 acre. There is enough of each kind to make it commercial.

Apples and peaches can be shipped in carload lots, while the other fruits are usually shipped, either with other growers or by express. The local market has been fairly good. The work of changing the farm from one-line production to many was necessarily slow, since we could not destroy the only source of income by removing the old trees. Over half of the apple trees were of unprofitable varieties and these were top-worked to more desirable kinds. The old trees were planted only 15 feet apart in the rows and half of the trees were pulled out. It was all done gradually and we suffered little in the quantitative reduction by gaining in quality. The top-grafted old trees bore their first crop last year and from now on we should just about double our production on the farm.

In spite of all this work, the farm has been paying and the main reason for this has been the quality of the fruit grown. The fruit growers in Delta County have taken a great interest in the farm and are frequent visitors. We believe we have demonstrated that we can grow fruit and this is, after all, what the growers want and expect.

Avon Farm

We wish to briefly outline our program at Avon, in order that the administration and the board may have a better or fuller knowledge of this important work. When this farm was purchased it was the intention to use it as a mountain vegetable demonstration farm

and to carry on certain experimental projects connected with the growing of vegetables. While these objects as stated still remain, our work, time and experience have shown us that vegetable production in the mountain sections of our state cannot be divorced from general crop production and livestock if it is to be permanent and profitable. Exclusive vegetable growing in the mountains is at best of short duration, for the reason that only a few kinds of crops can be grown due to climatic limitation and hence crop rotation cannot be practiced, nor can the fertility of the land be maintained. A general statement of the situation as we see it would read as follows:

Vegetable growing in our mountain sections should be carried on in connection with a well-organized system of general farming and livestock production. Vegetables should be included as a definite part in the system of crop rotation. It would be the cash crop. It would provide seasonable work for the help. The part and importance of vegetable growing in the general crop rotation should depend upon the farmer and his ability of handling the work. The livestock part of the program should be fully developed and include such kinds as can be carried. This would in many cases call for not only cattle, but sheep and, to a limited extent, hogs and poultry. The mountain sections as a whole are adapted to diversified agriculture including livestock. The crying need today is for more sources of income or crop diversification. The present condition in agriculture is due to over-specialization, resulting in over production of the stable crops.

With this in mind we have started a general program for operating the farm apart from the experimental projects: An 8-year crop rotation system has been adopted as follows: Potatoes first year after alfalfa, peas the second year, vegetables (lettuce, cauliflower, spinach, beans, etc.) the third year, grain seeded to alfalfa the fourth year, and the fifth, sixth, seventh and eighth years to alfalfa. Manure to be applied to grain and alfalfa fields. On the livestock side, we want to keep as many head and kinds as the farm can support. No grain, hay, straw or by-products are to be sold, but fed on the farm. On the other hand, no feed of any kind should be purchased. The farm should be self-sustaining or self-supporting in this respect.

The kind of livestock to be carried may well be a question of difference. However, we believe that we should raise our own stock, first to insure the right quality, second to make the farm independent from buying every year, and the uncertainty of obtaining the stock and kind wanted. Our aim is to have a fairly definite number to market every year, instead of a yearly investment.

In connection with the livestock program, we wish to make a confession. For several years past we have studied and dreamed about mountain farming in connection with the Avon farm and after some

experience and study we have reached certain conclusions, but knowing the impossibility of putting over a complete program at once because of lack of funds, we have been following the installment method of asking for a few things at a time.

Our confession is, that we hope to obtain permission to add 200 sheep and some brood sows to our livestock program. This expansion need not entail the expenditure of much money as we can build up in number after getting a foundation stock. Our desire is to develop a model farm and to demonstrate what can be done and what we mean when we preach diversified farming. We believe that it will be worth all that we can put into it and we hope you will agree with us. The experimental work should not suffer; in fact, we should be able to do this work under more favorable conditions.

State Horticulturist

The data for the year are not as yet available, and only a general statement can be made at this time. The peach crop was a total failure due to heavy spring freezes. The apple crop was normal and for what has been sold good prices were obtained.

The new cottage was completed at a cost of $2400.00, representing the profit of the last year. Mr. Green, in charge of the work on the Western Slope, had a busy season traveling over this large territory and giving help to the fruit growers. The orchard at Austin has had a signal influence on the growers and the industry. The growers are convinced that our institution knows how to operate a fruit farm and they constantly come to the farm to see how things are done and to ask for advice.

During the winter months growers' meetings are held all over the slope where their problems are discussed and where demonstrations in pruning and propagation are given.

During the packing season, demonstrations in packing and grading are held at different packing houses.

We have demonstrated that Colorado apples, properly grown, graded and packed, can compete successfully in the open markets. For 2 years in succession we have shipped a carload to the auction market in Chicago and have topped the market both times against the Northwest. This was done to show the growers that selling of the fruit is half accomplished if the grading and packing is properly done.

Each spring at the farm a demonstration is held to teach the growers how to make various spray mixtures at half the cost of the ready-made mixtures on the market. Instruction is also given on the washing and drying of the fruit to remove the arsenical residue. Many valuable data on fruit growing have been accumulated and these will be embodied in a general report of the state horticulturist.

The past season was on the whole a very favorable one for our work and progress was made on all projects. Particular attention was given to the bean and onion work with special reference to seed production in connection with the seed-certification program.

The report on work with small fruits is prepared by Richard V. Lott, horticultural assistant, as follows:

Small Fruits

1. **Varietal Trials of Red, Black and Purple Raspberries, Strawberries, Currants, Gooseberries and Grapes.**—In this work the standard varieties and all of the promising new varieties that can be obtained are used. At the present time there are growing on the station grounds, 18 varieties of red raspberry, 6 varieties of the black raspberry, 2 varieties of the purple raspberry, 5 varieties of the everbearing strawberry, 24 varieties of the June-bearing strawberry, 4 gooseberry varieties, 4 currant varieties and 12 grape varieties. There are also 25 plants of the Youngberry. New and promising varieties of each of these fruits will be added as they become available.

"The varieties of raspberries and strawberries that have given best results at Fort Collins are also being grown at the High-altitude Station at Avon. These trials have not been conducted long enough at either station to make definite recommendations.

"2. **Fruiting Habit of the Red Raspberry.**—Since the methods of pruning and training red raspberries vary widely in different sections of the state, this investigation was started in 1929 to determine the normal fruiting habit and the fruiting habit under different systems of training and pruning. The data that have been secured indicate that the most efficient method of pruning the Cuthbert red raspberry under the hill system of culture is thinning to 8 canes per hill and removing 12 to 15 inches from the tip of the cane. The data also indicate that the hedgerow system of training is preferable to the hill system, since the yield per cane was found to be inversely proportional to the number of canes per hill. It was found that in the Cuthbert red raspberry the yield per cane and weight per berry were significantly greater from canes of large diameter than from those of small diameter. This investigation will be continued using more varieties and also black raspberry varieties.

"3. **Time of Uncovering Red Raspberries.**—It has been found that the most desirable time for uncovering red raspberries in those sections where winter covering is necessary, is just before the buds start to push out into fruit spurs or vegetative shoots. Canes uncovered at this stage in both the seasons of 1928 and 1929 were subjected to near zero temperature without apparent injury to the fruit buds. When canes are uncovered after the buds have pushed out

shoots ½ inch or more in length there is often severe injury to these shoots from sudden drops in temperature, bright sunshine, or wind or all of these factors working together.

"4. **Grape Training.**—It has been found that the high renewal system of training to a 3-wire trellis is most desirable in these sections where winter protection is necessary. Under this system the canes can be easily laid down and taken up and the developing fruit gets the maximum amount of sunlight and air. Good light and air conditions are essential in the short growing season that prevails in many parts of Colorado."

The report on work with sweet corn by A. M. Binkley is as follows:

Sweet-Corn Improvement Work for Canning-Factory Varieties

"During the past few years there has been considerable increase in the acreage of sweet corn being grown for the canning factories. The quality of the corn being grown has not been up to the standards set for eastern producing sections and the yields have been deteriorating quite rapidly. This has been more especially true in the late varieties rather than with the mid-season varieties.

"In cooperation with the Kuner-Empson Canning Company, the work of improvement was started this year by selecting good strains of canning varieties of sweet corn for this state. There are two main varieties now being grown for canning—the Crosby Early and the Country Gentleman variety. The Crosby Early is probably the most popular of the canning varieties and it requires around 76 days to properly mature for canning in this state. The grains are medium sized, deep and very high in quality. The Country Gentleman is the leading late variety, requiring around 96 days to mature, and it produces small, fine grains which are very attractive when canned. They are small, slender and are packed so tight on the ear that when shelled they have the appearance of shoe pegs. The quality is as a rule very good in this variety.

"The problems of production have been such that the Kuner-Empson people have not been able to secure seed of high-yielding strains of these two varieties for their acreage in this state. Their particular problem with the Crosby Early variety was that the strain they were using had picked up a reddish blotch in the kernel which made it undesirable for canning. In accordance, we were furnished with samples of this variety and during the past growing season we have made selections for high yields, quality and freedom from the undesirable red blotch in the kernel.

Most of their trouble in securing good seed has come up in the Country Gentleman variety. They have found that the kernels, as produced in this state, will lose their peg-shaped type after growing one season under our climatic conditions. Instead of producing the same peg-shaped kernel, the kernels revert to a narrow, wide, flat type which is undesirable from the canning standpoint. It appears that in marketing the canned product the flat kernels are discounted on quality.

"The second problem with this variety is that the strains they have been using mature 10 to 15 days too late to secure the prime quality for canning. The third problem connected with the matter of selecting the best strains is that of barrenness. It appears now that the seed furnished to growers by the canning company is very high in the percentage of barrenness. In accordance, a strain test was conducted on the better strains of the Country Gentleman, furnished by commercial seed companies, and strains that were selected by the canning company men in the Brighton district. An improvement program was laid out which was planned for the purpose of selecting an early maturing variety, one which maintained its peg-shaped kernel and one which produced a small percentage of barren stocks.

"The results of this year's work have produced some very promising selections of pure-line individuals. The plan this past season was to select self-pollinated or pure-line individual plants and the process of stabilizing the desired characteristics started. After such plants have been inbred for two or three generations, it is planned to cross-breed such selections. Self-pollinated individuals as a rule lose vigor, are slightly reduced in size, and are low in yielding ability. Therefore, it is thought by crossing the inbred or pure-line strains that the vigor and yielding power can be brought back into the plants.

"The following table shows that the quality of the seed corn being used by the canning factories is very low and that there is considerable need for improvement by careful methods of selection. It will be noted that the percentage of barren stocks varies widely in different strains. This factor is of considerable importance to the growers of canning-factory sweet corn, as the yields are reduced from 33 to 65 percent per acre, due entirely to barren stocks in the field.

"From a study of the foregoing table it will be observed that there is a wide range in the days required to mature and the percentage of barren stocks. The seed that has been selected in this state shows a much smaller percentage of barren stocks in comparison with that from the middle western part of the United States. However, in all cases the time required to properly mature the corn for the canning factory is from 11 to 14 days longer than the standard

time required for the variety. The earliest maturing corn is the No. 2 strain of the E. B. Clark Seed Company, which matured in 98 days. However, the percentage of barren stocks was around 44 percent which makes it undesirable for use in this state.

CANNING-FACTORY SWEET CORN STRAIN TEST
COUNTRY GENTLEMAN VARIETY

Strain	No. of Hills	No. of Stalks	No. of Barren Stalks	Days to Mature	Percentage Barren
E. B. Clark Seed Co. No. 1	44	71	35	102	49
E. B. Clark No. 2	83	159	76	98	44
Hoopston Seed Co.	44	75	40	105	53
Home Grown No. 1 Brighton	88	194	73	103	37
Home Grown No. 2 Brighton	88	200	66	100	33

Time of maturity based on the number of days between date of planting and the date the ears were in full silk stage.

The most desirable strain from the home-grown viewpoint is the No. 2 selection of the seed grown at Brighton, Colorado. The percentage barren stocks amounted to 33 percent which is approximately 40 percent lower than the average of the seed secured from the commercial seed companies. There has been some progress made on early maturity. However, the strain is not quite high enough as far as quality is concerned. The table does not include the shape or character of the ear or the quality of the kernel, all of which must be considered in the selection of a desirable seed form.

"The results show conclusively that the quality of seed corn being used is very low and emphasizes the active need for seed-selection work. Unless this is taken care of it will be impossible for the canning companies to compete with the canned corn on the market as grown in the mid-western states."

The report on the work with horticultural seeds by Mr. Binkley is as follows:

Progress Report on Certification of Horticultural Seeds

The horticultural seed situation within the state and in the southern states is very unsatisfactory and has occasioned heavy losses to

growers. During the past growing season there have been many complete crop failures reported on a good many of the vegetable crops. A good percentage of these losses were reported principally on snap beans, due to the use of ordinary seed sold by seed companies which in many cases carried seed-borne diseases. The losses on pod pea and onion yields can also be largely attributed to the purchase and planting of poor seed.

Besides the losses experienced by growers in this state, there have also been many failures reported on such crops by vegetable growers in the southern and eastern states. During the past growing season there have been requests for high-grade snap-bean seed which requests ran up as high as 600,000 pounds of good seed. In addition there has been an active demand in the East for several thousand pounds of certified onion seed. Also, there have been requests for carefully selected cucumber and cantaloupe seeds.

In consideration of the above demands, it can be readily seen that there is an urgent call for certified seed for interstate trade. These states recognize the fact that Colorado is favorably located so far as soil, climate and elevation are concerned, to produce the highest-grade seeds obtainable. It can also be observed that from the unsatisfactory reports and the demand for good seed, the seed companies are not furnishing the growers with the quality seed they demand.

The problems confronted in the production of certified horticultural seeds differ considerably from those common to the growing of field crops. In the first place, the intensive cultural requirements of horticultural crops are such that they are grown on high-priced land and the production costs per acre are usually high. Furthermore, profitable crop requirements in horticulture call for high standards of earliness, uniformity and quality, coupled with high quantity production per acre.

In considering all the factors which enter into the profitable production of intensively grown crops, the seed planted is of the greatest importance. It is fundamentally important to know the yielding ability of varieties, their disease resistance, the uniformity in quality and the other factors which ultimately determine the market value of the crop. Therefore, in looking and planning ahead, the horticultural department has recognized these factors and their importance in producing a profitable crop. Recognizing the limiting factors in production as being more or less of a hereditary nature and seed borne, the certification plans were based on extensive variety trials.

In accordance, a pea-variety trial was started 3 years ago which contained something over 650 varieties of peas collected from all over

the world, for the purpose of standardizing and eliminating varieties which were unadapted to conditions within this state. As a result of this variety trial, we now have very superior strains of the Dwarf Telephone variety which are now being certified. During the past growing season, around 13,000 pounds of pod-pea seed were officially certified. In addition to seed certification, the department has been increasing foundation stocks of several of the varieties which have proved to be especially desirable for planting by the canning factories and the market growers. These foundation stocks have been increased so that the coming year more certification will be conducted on pod peas.

On snap-bean seed during the past growing season an extensive variety trial was conducted which contained all of the principal snap-bean varieties now being grown in this country and in Europe. The purpose of this trial is to study the different varieties observed and performance under our conditions and eventually select the most desirable ones for use in the state. Since the main difficulty in the production of snap beans comes from the transmission of three seed-borne diseases, it is essentially important that very careful attention be given to roguing and the selection of individual plants to eliminate the disease hazard. The department has been carrying on a selection and roguing of the Giant Stringless and Stringless Refugee for the past 3 years, and these 2 stocks are practically free from disease and are the increase from high-yielding individuals. During the past year there were around 40,000 pounds of late Stringless Refugee seed certified for use in this state. Of the Giant Stringless there were around 40,000 pounds certified from the original selected for interstate trade.

From the experimental side during the growing season of 1928, individual plant selections were made of the following varieties:

Burpee's Stringless Greenpod	Bountiful
Late Refugee	Refugee 1000 to 1

In addition to this, mass selections were made, both on the Littleton sub-station and at Fort Collins, from carefully rogued strains of

Black Valentines	Currie's Rust Proof
Full Measure	Davis White Wax

In summarizing the amount of bean-seed stock on hand at the present time for next season's work:

Increase in Foundation Stock—1929

Variety	Amount Grown Avon	Fort Collins	Western Slope
Davis White Wax	200 lbs.	100 lbs.	300 lbs.
Currie's Rust Proof	100	200	300
Burpee's Stringless Greenpod	1000	....	....
Bountiful	....	24 (2 strains)	....
Late Stringless Refugee	300	100	400
Early Refugee	1000	100	....
Black Valentine	Discard	150	....
Giant Stringless	100	40	....
Full Measure	....	125	....

The above list is from foundation stock increase and represents disease-free stocks. During the coming season it will be necessary to increase these selections on a mass scale in order to produce sufficient seed for distribution.

In carrying on the certification of horticultural crops it is the policy of this department to carry on a test plot of each strain of seed certified by the department. This policy is now being followed in connection with the certification of seed potatoes, and every grower is required to send a sample to the high-altitude farm for observation and study. This practice will also be followed in certifying vegetable seeds. It is very important. For example, the tendency is for snap-bean seed to pick up disease and run to flat pods. There are three seed-borne diseases which must be carefully checked before the seed can be certified. This can be partly accomplished by careful records taken during the germination and purity test by the state seed analyst and a further check will be had when the seed is planted in the test plots after it is certified.

At the present time there has been no onion seed certified because of the small acreage now being grown in the state. As with the other two above-mentioned crops, an onion variety trial has been started for the purpose of establishing a set type for each variety. After these varieties have been standardized, such seed as meets the requirements of the state horticulturist's office will be certified.

On vine-seed crops there is an active demand for certification, but due to the lack of standardization and confusion among seed-growers and the large number of varieties, no intensive certification program has been outlined. There has been a small quantity of cantaloupe seed of one established variety certified during the past season.

Estimated Amount of Certified Seed—1929

Pea Seed

Variety	Pounds of Seed Certified
Dwarf Telephone	1500 (14,000 rejected)

Snap-bean Seed

Variety	Pounds of Seed Certified
Stringless Refugee (Canning Type)	43,000 lbs.
Giant Stringless (Fresh Market Type)	40,000 lbs.
Total	83,000 lbs.

Cantaloupe Seed

Greeley Wonder	250 lbs.

The report on the work with onions was prepared by Earl J. Allen, and is as follows:

Report of the Work at the Rocky Ford Station—1929

1. **Onion Variety Trials.**—Yields were low in the variety trials, as was the case with all the onion yields, but very good comparative results were secured. The Valencia onion was first in tonnage produced, with the Denia and Gibraltar next in order. The Mountain Danvers gave the lowest yield. Detailed information resulting from these trials will be found in the accompanying tables.

2. **Onion Strain Tests.**—The strain tests gave some interesting results, showing marked difference in yield and demonstrating the value of a good source of seed. This information is also presented in tabular form.

3. **Transplants and Field-Sown Onions.**—In this project, an acre of each type of onions was grown. Exact costs of production, including harvesting, were kept on each plot. The cost of producing the acre of field-sown onions was \$108.93. That of the transplants was \$176.86. The yield for each acre plot was 426 crates. However, due to the variation in the amount each crate held, the exact yield for the plots will not be determined until the onions are sacked and weighed when sold.

4. **Storage of Onions.**—At the present time, several experiments are being carried on in regard to storage of onions. The results from this work will not be available until the storage season is over.

The projects being carried on are as follows:

1. A comparison is being made of onions kept in the experimental compartment, having added ventilation by means of bottom ventilators, as to onions kept in the check compartment, wherein ventilation is supplied with windows and doors only. Twenty-five crate lots of onions are being used in this experiment and loss in moisture and from rot will be determined.

2. Two crates of onions were topped very close to the bulb. Two crates were topped leaving a top length of 1 to 1½ inches. Rot and moisture losses are being determined.

3. Ten crates of cull onions, 10 crates of graded onions and 10 crates of field-run onions are being kept under similar conditions. Losses from rot and moisture are being recorded. The possibility of cull and rotten onions in field-run bulbs being a factor in causing loss in storage will be studied and the value of grading onions before storing considered.

4. Ten crates of onions were cured under canvas. These are being compared in keeping quality with 10 crates cured in the open.

5. In the field-curing project, 5 crate lots were used. In curing, the length of time the onions were cured in the field ranged from 1 to 21 days. The object of this experiment is to determine the length of time onions should be cured in the field, and whether or not thoro drying-out will improve their keeping qualities.

6. Fifty crates of the transplanted onions are being compared as to keeping qualities with 50 crates of field-sown onions.

7. Records are being kept on the onion varieties and strains in order to compare their keeping qualities.

8. The effect of freezing upon the keeping quality of onions in storage is being studied.

Cantaloupes.—Approximately 1 acre of the land was planted to cantaloupes for seed production. The vines were slow in getting started but were coming along nicely until the first part of September, when the entire patch became infected with rust, the vines going down at once. It was decided that the melons were too immature to harvest for seed and the project was abandoned.

ONION-VARIETY TRIALS

Stake No.	Variety	Yield Per Plot	Yield of U. S. No. 1					Yield of Culls	Yields per Acre		
			Large	Med.	Small	Ex. Lg.	Total		U. S. No. 1	Culls	Total
7	Ohio Yellow Globe	199	39.5	88.5	29.5		157.5	41.5	4899.82	1291.06	6189.89
8	Yellow Globe	220	106.5	70.5	16.5		193.5	26.5	6009.79	824.41	6844.2
9	Gibraltar	398	230.	84.5	19.5		334.	64.	10390.74	1991.04	12381.78
10	Denia	448.5	320.	75.5	21.		416.5	32.	12917.31	995.52	13912.83
11	Australian Brown	180	21.5	69.5	54.5		145.5	34.5	4526.61	1073.19	5599.8
12	Prizetaker	86	34.	29.	9.5		72.5	13.5	2255.48	419.98	2675.46
13	Arizona Str. Valencia	539.5	390.5	50.	5.		445.5	94.	13859.5	2924.34	16783.84
14	Aggeler-Musser Valencia	568	419.5	54.	8.5		482	86	14795.02	2675.46	17470.48
15	Yellow Globe Danvers	195.5	54.5	87.	24.		165.5	30.	5148.7	933.3	6082.
16	Mountain Danvers	134.5	56.5	50.5	18.		125.	9.5	3888.75	295.54	4184.29
17	Ailsa Craig	176	102.	25.5	4.		131.5	44.5	4090.97	1384.39	5475.36
18	Aggeler-Musser Valencia	482.5	391.5	33.5			425	57.5	13221.75	1788.82	15010.57
19	Yellow Globe Danvers	232	52.5	113.	27.5		193	39.	6004.23	1213.39	7217.52
20	Mountain Danver	128	59	49.5	12		120.5	7.5	3749.76	233.32	3981.08
21	Ailsa Craig	324	238	35.			273	51	8493.08	1586.61	10079.69
22	Ohio Yellow Globe	259.5	61	137	27		225	34.5	6999.75	1073.29	8073.04
23	Yellow Globe	259	132	89	15.5		236.5	22.5	7357.52	699.97	8057.49
24	Gibraltar	452	271	115.5	19.5		406	46.	12631.65	1730.06	14061.71
25	Denia	442.5	313	89.	17.		419	23.5	13035.09	731.08	13766.17
26	Australian Brown	140	29.5	67.	27.5		124	16.	3857.64	497.76	4355.4
27	Prizetaker	114.5	61.5	38	6.5		106	8.5	3297.56	264.43	3562.09
28	Arizona Str. Valencia	636.5	495.	52.			547	89.5	17017.14	2784.37	19801.51

AVERAGED RESULTS OF ONION-VARIETY TRIALS

Variety	Aver. Yield Per Plot	Yields Per Acre			Percentage Culls	Percentage U. S. No. 1	Percentage Stand	Corrected Yields Per Acre		
		U. S. No. 1	Culls	Total				U. S. No. 1	Culls	Total
Ariz. Valencia	588.	15438.32	2854.35	18292.67	15.63	84.37	38.16	40448.4	7478.39	47926.79
Aggeler Musser Valencia	525.2	14008.38	2232.14	16240.52	13.74	86.26	33.83	41909.53	6584.81	47909.53
Denia	445.5	13026.2	813.3	13839.5	5.87	94.13	40.83	31782.93	1984.45	33767.38
Gibraltar	425.	11511.19	1710.55	13221.74	12.93	87.07	44.66	25554.84	3797.42	29352.26
Ailsa Craig	250.	6292.02	1485.5	7777.52	18.95	81.05	23.16	27118.61	64025.	33521.11
Yellow Globe	239.5	6688.65	762.19	7450.84	10.22	89.78	32.5	30434.15	2339.92	22774.07
Ohio Yellow Globe	229.2	5949.48	1130.98	7131.46	15.85	84.15	42.5	14101.13	2657.8	16758.93
Yellow Globe Danvers	213.7	5576.46	1073.34	6649.76	16.14	83.86	40.83	19000.57	2887.28	17887.85
Prizetaker	200.5	2776.52	342.14	3118.66	10.97	89.03	15.5	17908.55	2206.8	20115.35
Australian Brown	160	4192.14	785.46	4977.6	15.77	84.23	37.16	11276.86	2112.88	13389.74
Mountain Danvers	131.2	3819.25	263.43	4082.68	6.45	93.55	22.33	17072.64	1177.53	18249.57

ONION-STRAIN TESTS (A SERIES)

Stake No.	Strain or Variety	Yield Per Plot Lbs.	Yield of U. S. No. 1 Large	Med.	Small	Ex. Large	Total	Yield of Culls	Yield Per Acre U. S. No. 1	Culls	Total
29	Assoc. Seed Co.	434.	218.	20.		117	355.5	76.5	13956.93	3081.91	17038.84
30	Arizona Strain	463	300.5	39.5		44	384.	79	15075.84	3101.84	18177.38
31	Aggeler Musser	592	412.	55.		43.5	510.5	82	20142.23	3119.32	23261.55
32	Pieter Wheeler	576	418.5	42.		49.5	510	66	20022.60	2591.16	22613.76
33	Burrell's Strain	653	492.5	38.		79.5	611	42.	23987.86	1648.92	25636.78
34	Ryan Bros.	490	334.5	18.5		94.	447	43	17549.22	1688.18	19237.4
35	Rohnert's Strain	217.5	137.5	45.5			183.5	34.5	7244.58	1393.47	8638.05
36	C. C. Morse	667	514.5	43.5		59.5	617.5	49.5	24243.25	1943.37	26186.62
37	Barteldes Riverside Strain	545	386	67		15	468	77.	18373.68	3023.02	21396.7
38	Hort. Dept. Selection C. A. C.	410	281	42.5		18.5	342	68	13426.92	2669.68	16096.6
39	Gum Strain	341	243.5	27.		15.5	286	55	11228.56	2159.3	13387.86
40	Pieter-Wheeler	432.5	352.5	40.5		7.5	400.5	32	15723.63	1256.32	16979.95
41	Burrell's Strain	448	346	28.5		31.5	406	42	15939.56	1648.92	17588.48
42	Ryan Bros.	340.5	260	18.5		34.5	313	27.5	12288.38	1079.65	13368.03
43	Rohnert's Strain	206	118.5	49			167.5	38.5	6576.05	1511.51	8087.56
44	C. C. Morse	537.5	432	41		36.5	509.5	28	19902.77	1099.28	21102.05
45	Barteldes Riverside Strain	553	411.5	54.5		24.5	490.5	62.5	19257.03	2453.75	21710.78
46	Hort. Dept. Selection	261	180.5	26.5		10.5	217.5	43.5	8539.15	1707.71	10246.86
47	Gumm's Strain	275	189	28.5		15.	232.5	42.5	9027.95	1668.55	10696.5
48	Associated Seed Co.	246	174.5	11.5		28	214	32	8402.64	1255.32	9657.96
49	Arizona Strain	327.5	220.5	31.		15	266.5	61	10452.79	2394.86	12847.65
50	Aggeler-Musser	279.0	206.5	27.5		5.5	239.5	39.5	9407.77	1550.77	10958.54

AVERAGED RESULTS OF ONION-STRAIN TESTS

Valencia Strain	Av. Yield Per Plot (Ranked)	Yields Per Acre						Corrected Yield Per Acre		
		U. S. No. 1	Culls	Total	Culls	U. S. 1.	Stand	U. S. No. 1	Culls	Total
C. C. Morse	602.2	22073.01	1571.32	23644.33	6.64	93.36	47.16	46794.78	3331.19	50125.97
Burrell's Strain	555.5	19963.71	1648.92	21612.63	7.63	92.37	38.66	51501.37	4254.21	55760.58
Barteldes Riverside	549.	18815.35	2738.38	21553.74	12.7	87.30	49.5	38007.03	5531.52	43538.55
Pieter-Wheeler	504.2	18873.61	1923.24	19796.85	9.71	80.29	38.33	46571.39	5000.42	51571.81
Aggeler-Musser	435.7	14775.	2335.04	17110.04	13.64	86.36	38.83	37971.75	6001.05	43972.8
Ryan Bros.	415.2	14919.15	1383.56	16302.71	8.48	91.52	28.	58484.07	5422.55	63906.62
Associated Seed Co.	340	11179.78	2168.62	13348.4	16.24	83.76	37.5	29738.22	5768.52	35506.74
Arizona Strain	395.2	12764.31	2748.2	15512.51	17.71	82.25	35.83	40611.43	7667.47	48279.9
Hort. Dept. Selection	335.5	10983.03	2188.70	13171.73	16.61	83.39	31.33	35135.86	6981.95	42117.81
Gumm's Strain	308.	10128.3	1913.88	12042.18	15.89	84.11	21.66	46691.38	8822.98	55514.36
Rohnert Strain	211.7	6910.31	1452.49	8362.8	17.36	82.64	30.33	22734.93	4778.68	27513.61

TOTAL COST OF GROWING AND HARVESTING ONE ACRE OF FIELD-SOWN ONIONS

Planting	Irrigating	Cultivating	Furrowing Out	Hoeing	Pulling	Topping	Preparation of Land	Rent of Land	Total Cost
Mar. 18 Man & Team 1 hr.	Mar. 19 4 hrs. 40 min. Apr. 2 4 hrs. 40 min. May 20 5 hrs. May 3 5 hrs. June 1 5 hrs. 14-5 hrs. 20-6 hrs. July 11 5 hrs. 26-5 hrs. Aug. 3 3 hrs. 17-3½ hrs.	Apr. 26-2 hrs. May 1-8 hrs. 23-6 hrs. 31 Man & Mule 2½ hrs. June 4 1½ hrs. 18-3½ hrs. 28-Man & Mule 2½ hrs. July 4 Man & Mule 2 hrs. 45 min. 23-2½ hrs. Aug. 13-2 hrs.	Mar. 19 Man & Mule 1 hr. June 1 Man & Mule 1 hr. 19-1 hr. July 8 Man & Mule 45 min. Aug. 2 1 hr.	May 27 4 hrs. June 5 6 hrs. 18-5 hrs. July 5 4 hrs. July 17 17-4 hrs. 30 min. Aug. 16 1 hr.	Sept. 19 4 hrs. 20-1 hr. 1 hr. 30 min. 20-10 hrs. 40 min. 21-1 hr.	Sept. 26 27, 28 426 crates @ 3c	$4.16	$50.00	
Team Hr. @ 40c 1 hr. Man Hr. @ 30c 1 hr.	Man Hrs. 51 hrs. 50 min.	Single horse @ 20c 5 hrs. 45 min. Man Hrs. 33 hrs. 15 min.	Team Hrs. 45 min. Single Horse Hrs. 2 hrs. Man Hrs. 4 hrs. 45 min.	Man Hrs. 24 hrs. 30 min.	Man Hrs. 17 hrs. 10 min.				
$0.70	$15.55	$11.12	$2.12	$7.35	$5.15	$12.78	$4.16	$50.00	$108.93

TOTAL COST OF GROWING AND HARVESTING AN ACRE OF TRANSPLANTED ONIONS

Setting Out Plants	Irrigating	Cultivating	Furrowing Out	Hoeing	Pulling	Topping	Preparation of Land	Rent of Land	Total Cost
Apr. 17 66 hrs. 30 min. Apr. 18 59 hrs. Apr. 26 58 hrs. May 10 16 hrs. May 2 16 hrs. May 11 2 hrs. May 13 5 hrs.	Apr. 10 4 hrs. 13-8 hrs. May 9-4 hrs. 13-4 hrs. 21-3 hrs. June 1-5 hrs. 3-5 hrs. 14-5 hrs. 20-7 hrs. July 10-5 hrs. 26-4 hrs. Aug. 3-3 hrs. 17-3 hrs. 30 min.	May 4-10 hrs. 23-6 hrs. 31-Man & Mule 2 hrs. 30 min. June 5 1 hr. 30 min. 18-4 hrs. 28-Man & Mule 2 hrs. 30 min. July 4 Man & Mule 2 hrs. 30 min. July 25 2 hrs. 40 min. Aug. 1 13-2 hrs.	Apr. 10 Man & Team 1 hr. June 1 Man & Team 19-1 hr. July 8 Man & Team 45 min. Aug. 3-1 hr.	June 5 7 hrs. 18-3 hrs. 30 min. July 5 5 hrs. 19-4 hrs. Aug. 16 1 hr.	Sept. 17 4 hrs. 19-2 hrs. 30 min. 20-10 hrs.	426 crates @ 3c	$4.16	$50.00	$66.75 18.75 11.60 2.32 6.15 4.95 12.78 4.16 50.00
Man Hrs. @ 30c 222 hrs. 30 min.	Man Hrs. 60 hrs. 30 min.	Single Horse @ 20c 7 hrs. 30 min. Man Hrs. 33 hrs. 40 min.	Team Hrs. @ 40c 1 hr. 45 min. Single Horse 1 hr. Man Hrs. 4 hrs. 45 min.	Man 20 hrs. 30 min.	Man 16 hrs. 30 min.				
$66.75	$18.75	$11.60	$2.32	$6.15	$4.95	$12.78	$4.16	$50.00	$178.86

Broccali. Four rows, approximately 125 feet long, of this crop were set out. The plants seemed to do very well, but due to my unfamiliarity with the crop and to lack of knowledge as to how it was harvested, no yield records were taken. From the success that growers in the Pueblo district had with broccali during the past year and from its seeming adaptiveness to the Rocky Ford district, it would be well to carry on further trials with this crop during the coming year.

Tobacco.—Plants of four varieties of tobacco, namely, Banner of Brazil, Leaf, White Burley, Havana and Cuban Shade, were sent down from Fort Collins. These were set out but a great number failed to live. Replants were obtained but an error was made in replanting which so hopelessly mixed the varieties that it was impossible to differentiate between them. The plants grew very well but the one hail of the season came during the second month of the summer and so badly riddled the leaves of the plants that the quality was ruined. This seemingly indicates that tobacco as a commercial crop would be too risky a proposition in a region subject to hails.

Cauliflower.—Two thousand plants of the Early Snowball variety were set out along with approximately 100 plants each of the Danish Perfection and Matchless Spring varieties. These plants did not do very well. Growth was slow. Harvesting commenced during the latter part of July. A total of 871 heads were cut; of this number 29.60 percent were good, 44.64 percent ricy, 21.92 percent leafy and 3.44 percent had thrown up seed stalks. The remainder of the crop was in such bad shape from attacks of grasshoppers and cabbage worms that harvesting was stopped.

Carrots.—Due to the increased interest in carrots as a commercial crop, a few varieties were tried out. These varieties were: The

YIELD OF CARROTS BY PLOTS

Plot No.	Variety	Yield Per Plot	Yield Per Acre	
51	Hutchinson	229.5	37,488.82	
52	Long Orange	125.5	20,500.42	
53	Oxheart	282	46,064.7	Plots
54	Chantenay Half-Long	133.5	21,807.22	160 ft. long
55	Danver's Half-Long	127.5	20,827.12	
56	New Coreless Nantes	24.5	4,002.07	
57	Danver's Half-Long	299.	69.774.64	
58	New Coreless Nantes	49.5	11,551.32	
59	Long Orange	87.	20,302.32	Plots
60	Hutchinson	108.5	25,319.56	112 ft. long
61	Oxheart	190.	44,338.4	
62	Chantenay Half-Long	83.	18,368.88	

AVERAGE YIELD OF CARROTS

Variety	Yield Per Acre
Hutchinson	31,404.19
Long Orange	20,401.37
Oxheart	45,171.55
Chantenay Half-Long	20,588.05
Danver's Half-Long	45,300.98
New Coreless Nantes	4,276.69

Hutchinson, Long Orange, Oxheart, Chantenay Half-Long, Danvers Half-Long and the New Coreless Nantes. The results obtained are presented in tabular form.

Respectfully submitted,

E. P. SANDSTEN, Horticulturist.

REPORT OF THE IRRIGATION ENGINEER

To the Director:

I wish to submit the following as a brief report concerning the work of this section during the past 12 months:

Pumping Project.—This project was started in 1928 and is supported by state funds. Resulting from the preliminary survey of the state, a brief report was prepared by W. E. Code, entitled, "Suggestions Concerning Small Irrigation Pumping Plants," which was published by the Experiment Station as bulletin 350, January, 1929. During the past summer season a detailed study was made in Weld County for the purpose of determining the relative costs of irrigation by pumping and that supplied as ditch or reservoir water. Thirteen individual farms were under consideration, where five were served by ditch and reservoir water, and eight served by pumping from wells and low-lying laterals.

This study also included the gathering of data relative to crop production, soils and other pertinent facts. During the past 2 years, data have been collected as to underground water-bearing areas in various parts of the state, and it is intended to ultimately prepare maps indicating the areas most probable for dependable underground water supplies.

Measurement of Water.—This project has been active for a number of years and was originally carried as an Adams project; later the work was supported by Hatch funds, and at present by both Hatch and state funds. Government funds have been used to support this project since its inception. Under this project has come the development of the improved Venturi flume, which at present is concerned with large-sized structures.

In December, 1928, a 40-foot reinforced concrete improved Venturi flume was completed on the Fort Lyon Canal near La Junta, the largest yet constructed. Since its completion a number of current-

meter check measurements of the rate of discharge have been made. These measurements appear to agree remarkably close to the computed value, where the conputation is based on the law of flow set up at the time the structure was designed. Measurements made on the 20-foot reinforced-concrete improved Venturi flume on the Holbrook Canal near Rocky Ford, built October, 1927, show very close agreement with the law of discharge. For submerged-flow conditions on this Holbrook flume, tests indicate a marked consistency in the relation to the computed discharge. Because of the apparent reliability of these large flumes now operating under conditions which heretofore were entirely unsatisfactory, there is now contemplated the installation of several more large flumes of this type on the canals diverting from the Arkansas River between Pueblo and the Kansas state line.

Information has reached us from the Hawaiian Islands to the effect that a large number of the smaller-sized improved Venturi flumes and now in use in the measurement of irrigation water on several of the large sugar plantations. Communications from many foreign countries cite the use of this measuring devise.

At the hydraulic laboratories a new type of measuring device is being investigated called the adjustable tube meter which is intended for the measurement of relatively small flows, that is to say, less than 50 second-feet. The experimental model has a capacity of about 7 second-feet. This device possesses the following desirable characteristics: The ability to operate under excessive sand or silt conditions; measurement with small loss of head, or, in other words, in a channel of slight grade. It is so equipped that the rate of discharge can be determined by the simple multiplication of two indicated values. It is believed that when this new scheme is fully developed, it will be possible to successfully meet all conditions of measurement under irrigation practice. This adjustable tube meter will be particularly well suited to the distribution of the water supply to the farmer which will result in a more equitable apportionment, a greater satisfaction to the user, and a tendency to broaden or increase the beneficial use of the present water supply which is of inestimable value.

Instruments have been developed as accessories both to the improved Venturi flume and the adjustable tube meter. A double-head recording instrument has recently been perfected to be used in connection with the flume, especially the large sizes now in use in the Arkansas Valley. The instrument, as an accessory to the adjustable tube meter, indicates the square root of the difference or effective head, where this reading, multiplied by another indicated constant, gives the rate of discharge.

Some special work has been done at the Bellvue laboratory in connection with a study of the measured discharge by use of the current meter in comparison with this identical flow over a standard calibrated rectangular weir. This work is primarily to round out the previous current-meter study and incidentally to provide basic data for guidance in the current-meter measurements in the field on the discharge thru large improved Venturi flumes where the depth of water is comparatively shallow.

A few days were spent at the Bellvue laboratory during November in making some preliminary studies as to the recovery of head in an outlet transition section.

Evaporation from a Free Water Surface.—This project, carried cooperatively on government funds, and supported by Hatch and state funds, has been virtually completed. A detailed report covering this extensive study has been prepared by Carl Rohwer. This report includes the results of the laboratory work done here at Fort Collins, as well as studies made at various points thruout the West in the determination of the relation of altitude to the rate of evaporation. To complete the full range of altitude, Mr. Rohwer made observations at Imperial, California, at an elevation of 68 feet below sea level, and at the summit of Pikes Peak at an elevation of 14,109 feet above sea level. This report is to be published as a bulletin issued by the U. S. Department of Agriculture. Subsequent to the preparation of this report, a series of evaporation observations has been conducted, where the water surface was covered with a thin film of light oil.

In connection with this project, there has been conducted a minor study on the rate of evaporation from the surface of moist soils and sands, with water tables at 1, 6 and 12 inches below the evaporating surface. This last season the moist-soil equipment was altered so as to have the water table at 6, 12 and 18 inches below the surface, and instead of maintaining an exposed surface void of vegetation, there was provided a sod covering of blue grass and sedge or swamp grass, in duplicate in the tanks having the different water tables. Check tanks were maintained without crop.

Meteorology.—This has been a continuing project for many years and is supported wholly on state funds. R. E. Trimble, observer, who has had charge of this work for about 39 years, has prepared a report on the Climate of Colorado, published as Bulletin 340, Colorado Agricultural Experiment Station, December, 1928. This bulletin reports the averages for the past 41 years for Fort Collins, as well as for a period of years for other points in Colorado where cooperative weather stations are maintained.

Project Work for the Coming Year.—Projects which are to be given attention next year will be the continued study on the large improved Venturi flume, with the ultimate view of preparing and publishing a report covering the investigation of the larger sizes of this type of measuring device. This will be under the general project on measurement of water. Under this same project, it is expected that further work will be conducted on the subject of weirs, and at the conclusion of which a revision of the entire study on weirs will be prepared for publication. The matter of further extended research on the adjustable-tube meter is highly desirable, and it is the intention also at this time to test this device in the laboratory for discharges of 50 to 75 second-feet. This work is also under the project on measurement of water.

The project on pumping for irrigation and drainage will be continued. No definite plans as to a special field study for next year have been made, but because of all the necessary equipment available for such a study, it is believed to be highly desirable to continue at least one more year in the study of the relative costs of ditch and pumped water for irrigation. General observations on pumping and well data will be secured, also detailed information on the study of a well near Eaton which is expected to show results from the standpoint of pumping for drainage.

The work on the evaporation from moist soil surfaces will be continued, where sod grass is maintained as previously described. This work will be done under the project on evaporation.

Published Articles.—Only one article has been contributed for publication outside of the official bulletins, namely, Experiments to Determine Rate of Evaporation from Saturated Soils and River-bed Sands, by R. L. Parshall, appearing in the April, 1928, Proceedings of the American Society of Civil Engineers.

Respectfully submitted,
R. L. PARSHALL, Irrigation Engineer.

SECTION OF VETERINARY PATHOLOGY

To the Director:

Sheep Losses in Feedlots

Coccidial dysentery seems to be unusually prevalent this fall, we having been privileged to study six different outbreaks. While the disease has affected several hundred lambs, the mortality is comparatively small, especially when skillfully treated.

There were also an unusual number of cases of pneumonia giving us opportunity to extend our observations on the bacteriology of this condition.

We were able to find another outbreak of paratyphoid dysentery which is the first since the large epidemic we described in 1923. We have submitted a paper on this outbreak for publication. The history indicates that going without feed and long-distance shipping were large factors in the causation of the disease. The total loss out of 1600 lambs was only 30.

At the request of the U. S. Biological Survey we carried on a few experiments on the toxicology of thallium sulphate with sheep. A sheep weighing 83 pounds and receiving 14 grains of thallium sulphate mixed with oats died in 9 days. One weighing 103 pounds and receiving 7 grains of the poison, survived but lost most of its wool. In other animals the loss of hair is considered quite typical of thallium poisoning, but it was not known until now that the same result would be had with sheep. This work will shortly be offered for publication.

Death Losses in Lambs on Heavy Grain Feed

The work on the presence of spore-bearing pathogenic anerobes in the spleens of sheep has been finished and accepted by the Journal of Infectious Diseases for publication. It shows that 66 organisms of this type were encountered in the spleens of 200 sheep. Of these 66, 58 were C. edematis; 6, C. welchii and 2, C. novyi. On the basis of the clinical diagnosis, it is apparent that these organisms have no relation to overeating nor any of the other clinical diseases in which they were found. The longer the animal has been dead the greater is the likelihood of one of them being isolated from the spleen, indicating that they are merely cadaver bacilli.

The examination of the urine of cases of overeating continues to reveal quantities of sugar in most instances.

Icterohematuria

The survey of this disease in the state made by Dr. Floyd Cross during the summer shows that it is most prevalent in the mountainous area of Jackson, Grand, Routt and Moffat counties, with single outbreaks occurring in sheep from Lake, San Miguel and Dolores. The survey shows that during the last 9 years the disease has not materially increased as we had presumed, but that it develops in proportion to the new sheep brought in and run under our mountainous condi-

tions. The high point was reached in 1927 when 614 animals were lost from this disease. Apparently the heaviest loss comes in the first winter after the animals have been ranged on our forest reserves. Following this the disease subsides until outside animals are again imported. The solution seems to be to raise our own breeding stock as far as possible.

Contagious Abortion

The college herd continues clean.

The range-management herd suffered a serious outbreak in February of this year, due, as we learned later, to neighboring cattle being allowed to water in the same lake with our range animals. By 30-day testing and sale, the herd now appears again to be clean.

The herd at Fort Lyon suffered three successive waves of re-infection in the course of approximately 2 years. This finally resulted in the infected herd being moved to an entirely different farm, since which time the clean portion has passed two tests without a reactor.

Abortion disease as transmitted to man going under the names of undulant or malta fever, is receiving increasing attention. Two human cases have come under our observation, both of which gave positive agglutination tests and from one of which we were able to isolate the organism from the blood stream. The report of one of these cases has been published in "Colorado Medicine" in collaboration with Dr. J. D. Carey in whose practice the case occurred.

Coccidiosis in Cattle

We must again report no progress on this project thru lack of material and time of the workers.

General

Tabulation of our diagnostic work done in the laboratory follows:

Avian	693	Miscellaneous	423
Bovine	278	Ovine	63
Canine	97	Rodents	25
Equine	25	Suis	44

Baby chicks examined for white diarrhoea	151 lots	100 positive
Examinations for rabies	59	29 positive

Blood Tests

Contagious Abortion (Bovine)	2992	705 positive	23.56 percent positive
Contagious Abortion (Swine)	40	6 positive	15.00 percent positive
White Diarrhoea	10704	1121 positive	10.47 percent positive

Respectfully submitted,

I. E. NEWSOM, Veterinary Pathologist.

REPORT OF THE VETERINARY SECTION

To the Director:

In the Veterinary Section there is but one project, that of animal diseases. This is a state fund project and as the name indicates, is a general project and does not contemplate prolonged field and laboratory investigations. Such work is carried on in the Section of Veterinary Pathology. We are cooperating by supplying material for both clinical and laboratory diagnosis and by field observations.

Diseases of livestock that were conspicuous a few years back are now relatively unimportant. New disease conditions are constantly appearing and must be met by adequate phophylactic and thearapeutic measures. Malignant catarrhal fever has been quite prevalent but in most instances has appeared in a mild form. Among the newer diseases, or perhaps more appropriately, those which have more recently been recognized, are anemia in pigs, preparturient paralysis in ewes, coccidiosis in several species of farm animals, paratyphoid conditions, undulant fever associated with the abortion disease of cattle, and chronic progressive pneumonia of sheep.

The heavy losses of lambs in the feedlots appears to be caused both by over-feeding of concentrates and a variety of infections. No one infection stands out conspicuous in this respect. The vitality of animals and shipping conditions seem to constitute the key to shipping losses.

We wish to continue with the one project of animal diseases. Articles written for publication have been in connection with the editorial news service of the college, and for farm journals.

Respectfully submitted,

GEO. H. GLOVER, Veterinarian.

ENGINEERING DIVISION

To the Director:

I am transmitting the annual reports of the Civil Engineering and Mechanical Engineering Sections of the Engineering Division of the Experiment Station.

Respectfully submitted,

L D CRAIN, Chairman and Vice-director.

REPORT OF THE CIVIL ENGINEER

To the Vice Director:

I submit herewith the annual report of the Civil Engineering Section of the Colorado Experiment Station.

The work of this section during 1929 may be summarized under three main divisions:

1. Research and experimentation.

2. Testing highway materials for use in state and federal-aid roads.

3. Cooperative testing and investigation of materials and processes which are to be used in actual highway construction and the use of information so gained as a basis for conclusions in connection with Experiment Station projects.

I. The work under research and experimentation has been confined to one project, the heaving of concrete slabs, which was started in the winter of 1927-28 under the supervision of D. J. Tripp. Before his resignation on September 1 of this year, Mr. Tripp tabulated all the data which had been collected on the experiment up to August 1, 1929. From this data he plotted curves of slab movements, soil temperatures and soil-moisture conditions and wrote a progress report of the entire project from its start up to August 1, 1929.

It is our opinion that sufficient data have not yet been collected to form a basis for any definite conclusions as to the effect of subsoil heaving on concrete slabs. It is, therefore, thought advisable to continue the observations thru another winter and summer and at the same time, to make some observations on slabs of pavement in actual service to supplement those on the test slabs. I have consulted Mr. Maloney, assistant engineer of the State Highway Department, and have his sanction on my proposal to place plugs and reference bench marks in the pavement for the purpose of making these supplementary observations. The data up to the present time show a very small and an irregular movement in the slabs. If future data are the same we shall get little out of this experiment.

Nothing has been done on the project recently outlined and submitted by Mr. Tripp on light asphaltic road surfaces. A similar experiment has been outlined by the Bureau of Public Roads to be worked out this coming season somewhere in the West and my first thought on learning of this, was that we should drop this project in order to avoid duplication of work. However, after talking with

Mr. Maloney and with Mr. Williamson of the Bureau of Public Roads, I find that the bureau's project may be carried out in New Mexico or even as far away as California, which would mean that results obtained would not apply to conditions in Colorado. In that case, I believe we should plan to carry out the experiment next summer. Mr. Maloney expressed the belief that the State Highway Department would be willing to construct the road which would consist of about 10 miles of experimental sections ½ to ¾ miles each in length, as a part of the 1930 improvement program, the specifications for each section to be written jointly by the testing engineer at this institution and the highway engineers, and all data and observations to be taken by the testing engineer of this institution.

It is my opinion that the 1 year suggested by Mr. Tripp in his outline of the project would be inadequate to allow us to observe the wearing qualities and maintenance costs on such a road and I would suggest that at least 3 years be taken in which to make observations before we draw our final conclusions. It is true that much will be learned in the first winter after the road is built and this knowledge will be immediately available as a tentative guide in building future roads, but I feel that our final conclusions should be based on more mature observation.

II. Testing materials, concrete cylinders and pavement cores for the State Highway Department has composed a large part of the laboratory work during the past year. A total of 1755 samples and test specimens has already been tested since January 1, 1929 and this total will reach approximately 1900 by December 31. Of the specimens handled up to date, 1476 were concrete cylinders from new pavement and structural work; 130 were subsoil samples; 30 were surfacing material for oil treatment; 6 were surfacing aggregates not to be treated; 64 were road oils; 44 were concrete core samples of old pavement and 5 were asphalt.

We now have on hand 163 cores; 621 soils and 15 oil samples which we shall work on this winter while road work is quiet. It will take all our laboratory force all winter to do this work.

III. Under the heading of cooperative testing, some work was done during the year on oil mixtures and also on subsoils. It is my understanding that samples of road oil were sent in for tests by the highway department and that while these tests were being run, mixtures were made of the oils and the mixtures were also tested with the idea of arriving at a method of controlling the product to be used by blending or mixing oils having varying properties.

Samples of subsoil sent in by the highway department were tested for stability as pavement foundation and the data obtained in addition

to being reported for the information of the Highway Department were preserved and used as a basis for conclusions in connection with our own subsoil studies for the Experiment Station.

Since taking over the work of testing engineer on October 1, 1929, Mr. Carpenter has found it necessary to make rather extensive repairs on much of the equipment in the laboratory and he now has in mind several improvements which, while not expensive, will greatly improve the appearance of the laboratory and expedite the work therein.

Respectfully submitted,

E. B. HOUSE, Civil Engineer.

Approved: L D CRAIN, Vice-director.

REPORT OF THE MECHANICAL ENGINEER

To the Vice-director of the Experiment Station:

Following is the annual report of the Mechanical Engineering Division of the Experiment Station of the Colorado Agricultural College.

During the past year, this section has devoted its time to the following projects: Proximate analysis of Colorado coals, ventilation of new library, drying potatoes for stock feed, and gasoline economy in automobile engines.

Project No. 1 was completed during the year. Samples of the commercial coals in northern fields of Colorado, North Park, and Southern Wyoming were tested for moisture, volatile matter, ash, fixed carbon, and B. T. U. content. Results of these tests are kept on file for use in determining the particular coal to buy for a given purpose.

Project No. 2 was an investigation to determine the reason why the ventilating system of our new library did not give the required results. This investigation demonstrated that the system was not properly installed. Corrections were made so the system would work perfectly.

Project No. 3 was an investigation of the commercial value of drying potatoes for stock feed. Such food has been used to a limited extent, but our investigation demonstrated the doubtful commercial value of a plant to operate on a large scale. The price of potatoes

usually would prohibit their use in the manner considered. The cost of drying, also, would make this feed too expensive.

Project No. 4.—The work on this project consisted of assembling the apparatus for the tests. This assembling has been only partially completed.

In addition to the above projects, many samples of lubricating oils have been tested for various persons.

In June, 1929, Charles A. Logan, the assistant in charge of our research work in this department, resigned, the resignation to become effective September 1, 1929. A successor to Mr. Logan has not yet been appointed. For this reason research work in the department has been suspended pending the selection of a new worker.

Respectfully submitted,
L D CRAIN, Mechanical Engineer.

REPORT OF THE EDITOR

To the Director:

Practically the same amount of editorial work has been done for the Experiment Station this year as last. Seventeen bulletins, 4 press bulletins and the annual report, totaling 756 pages have been handled, as compared with 752 pages in 1928.

Fully 30 percent of the 647 stories sent out in our mimeographed news service have been from station workers or about station work.

We have cooperated with workers in charge of farmers' day at Avon, the farmers' day at Akron, and both feeders' days on the campus, in getting suitable announcements and information to the farmers and feeders.

Following are the publications issued during the past year:

Experiment Station Publications

Bul. 335—Range Resources of The San Luis Valley.
62 pages. 3,000 copies.

Bul. 338—Financing the Western Cattleman.
88 pages. 2,000 copies.

Bul. 340—The Climate of Colorado.
68 pages. 2,000 copies.

Bul. 341—Ants and Their Relation to Aphids.
96 pages. 1,700 copies.

Bul. 344—The Principles of Bread-making.
38 pages. 4,000 copies.

Bul. 345—The Australian Saltbush.
28 pages. 1,200 copies.

Bul. 346—Farm Taxation in Colorado.
48 pages. 3,000 copies.

Bul. 347—Use of Carbon Disulfide for the Eradication of Perennial Weeds. 24 pages. 3,000 copies.

Bul. 348—Canada Thistle and Russian Knapweed and Their Control.
44 pages. 3,000 copies.

Bul. 349—Effect of Lumnite Cement and Plaster Paris Caps on the Strength of Concrete Test Cylinders. 16 pages. 1,500 copies.

Bul. 350—Suggestions for Small Irrigation Pumping Plants.
24 pages. 7,000 copies.

Bul. 351—Some Common Diseases of Ornamental Plants.
28 pages. 3,000 copies.

Bul. 352—Sulphide Sulphur Content of Sprays.
12 pages. 2,500 copies.

Bul. 353—Factors Influencing Cost of Production.
72 pages. 2,500 copies.

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Bul. 356—Improvement of Sagebrush Range in Colorado.
12 pages. 2,000 copies.

Press Bul. 67—A New Smooth-awned Barley for Irrigated Conditions in Northeastern Colorado. 4 pages. 3,000 copies.

Press Bul. 68—Progress Report of Livestock Feeding Experiment, 1929. 8 pages. 2,000 copies.

Press Bul. 69—Progress Report. Fattening Rations for Pigs.
8 pages. 2,500 copies.

Press Bul. 70—Summary of 1928 and 1929 Tests. Fattening Rations for Calves. 8 pages. 2,500 copies.

Forty-first Annual Report. 48 pages. 1,500 copies.
Cattle Feeders' Day Programs (Tenth Annual). 8,000 copies.

Respectfully submitted,

I. G. KINGHORN, Editor.

THE STATE AGRICULTURAL COLLEGE
OF COLORADO

THE FORTY-THIRD ANNUAL REPORT

— OF —

The Colorado Agricultural Experiment Station

FOR THE SHORT PERIOD 1930

THE STATE AGRICULTURAL COLLEGE
OF COLORADO

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The Colorado Agricultural College

FORT COLLINS, COLORADO

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FINANCIAL REPORT OF THE EXPERIMENT STATION

For the Year ending June 30, 1930

	Hatch Fund	Adams Fund	Purnell Fund	State Mill Levy Fund	Special Fund	Pure Seed Fund	Irrig. Cash Fund	Total Funds
DR.								
Balance July 1, 1929				$9,512.07	$ 11,792.83	$ 13,267.22	($ 383.48)*	$ 34,188.64
From the Treasurer of the United States as per appropriations for the fiscal year ending June 30, 1930, under acts of Congress approved March 2, 1887, (Hatch Fund), March 16, 1906, (Adams Fund), and February 24, 1925, (Purnell Fund)	$15,000.00	$15,000.00	$60,000.00					90,000.00
Other sources than the United States				113,389.65	33,105.35	3,500.00	4,505.00	154,500.00
	$15,000.00	$15,000.00	$60,000.00	$122,901.72	$44,898.18	$16,767.22	$4,121.52	$278,688.64
CR.								
To Salaries	14,738.17	15,000.00	50,790.17	28,432.54	17,696.11	6,505.66	3,232.90	136,395.55
Labor			2,065.66	26,820.49	879.19	755.86	230.00	30,751.20
Stationery and Office supplies			152.65	1,761.76	275.99	134.40	48.90	2,373.30
Scientific supplies, consumable			610.35	2,053.39	946.27	52.36	4.92	3,667.29
Feeding stuffs			163.13	11,427.71	230.48			11,821.32
Sundry supplies			192.56	3,858.98	347.46	54.43	3.10	4,456.53
Fertilizers			20.00	162.62				182.62
Communication service			90.04	1,410.91	50.18	10.47	6.45	1,568.05
Travel expense			3,832.23	8,894.50	1,713.49	735.19	586.90	15,762.31
Transportation of things			21.07	1,020.39	18.07	1.23		1,060.76
Publications	261.83		129.18	3,449.92	183.37			4,024.30
Heat, light, water, power				731.12				731.12
Furniture, etc.			586.17	1,024.36	13.59	122.43		1,746.55
Library			122.02	965.02	53.85	11.00		1,151.89
Scientific equipment			531.56	2,484.50	742.20	246.38		4,004.64
Livestock			104.10	11,604.32	58.50			11,766.92
Tools, machinery, appliances			4.75	3,606.43	3.25			3,614.43
Buildings and land			570.01	6,149.70	1,342.74	102.65	2.35	8,167.45
Contingent expenses			14.75	208.87	28.10	35.16	6.00	292.88
	$15,000.00	$15,000.00	$60,000.00	$116,067.53	$24,585.84	$8,767.22	$4,121.52	$243,539.11
Balance on hand June 30, 1930				6,834.19	20,315.34	8,000.00		35,149.53
Grand Total	$15,000.00	$15,000.00	$60,000.00	$122,901.72	$44,898.18	$16,767.22	$4,121.52	$278,688.64

(* Overdraft)

LETTER OF TRANSMITTAL

To His Excellency, William H. Adams, Governor of Colorado:

In accordance with the law of Congress establishing Agricultural Experiment Stations, I have the honor to transmit the Forty-third Annual Report of the Colorado Agricultural Experiment Station.

The report contains brief summaries of the work done by those in charge of the different sections of the Experiment Station, as well as a full list of projects upon which work has been done. However, because of the change in the state fiscal year to make it conform to the federal fiscal year, the present report covers the 7-month period from December 1, 1929, to June 30, 1930, only.

C. P. GILLETTE, Director

Agricultural Experiment Station
Fort Collins, Colorado
June 30, 1930.

AGRICULTURAL DIVISION

Report of the Director

To the President:

I am presenting the forty-third annual report upon the work of the Colorado Agricultural Experiment Station for the 7 months ending June 30, 1930. The report also contains a financial statement of all funds received and disbursed during the same period.

The changes in personnel of the station staff have been few. The spirit of cooperation among the workers, and between the various sections and the branches of the United States Department of Agriculture, has been good and some very important results have been reached. Some of these results have already been published in station bulletins, or in scientific journals of the country. The number of bulletins giving the results of investigations has been larger than for any like period in the history of the station.

There are no indications that we shall receive, either from federal or state funds, any increase in our revenues during the coming fiscal period to enable us to meet the demands for additional lines of research in the interests of agriculture, home economics and mechanic arts. We shall be compelled to confine our growth to greater efficiency in the expenditure of present funds without attempting a larger program than has been carried during the past year.

In accord with the spirit of modern agriculture and the recommendations of the Federal Farm Board, it shall be our effort to improve the agricultural conditions of our state thru researches that will improve quality rather than quantity production upon the farms and ranches and in the orchards of the state.

The station projects upon which work has been carried during the past year, including a few new ones which have recently been approved, are as follows:

AGRICULTURAL DIVISION

Agronomy Section

Relation of Soil Moisture, Structural Development and Acre Yields in Small Grains Adams and State funds.

Correlation of Characters in Grains. Hatch and State funds.

High-altitude Crops. State funds.

Plains Crops and Management. State funds.

Improved Seed. State funds.

Control of Excessive Soil Nitrates in the Arkansas Valley. Purnell and State funds. (Cooperative with Bacteriology).

Studies in the Control of Bacterial Wilt and Winter Killing. Purnell and State funds. (Cooperative with Bacteriology).

Laboratory Methods of Measuring Soil Fertility. Purnell and State funds. (Cooperative with Bacteriology).

Animal Investigations Section

Ration Experiments with Cattle. State funds.
Summer Cattle-fattening Experiments. State funds.
Range and Pasture Improvement. State funds. (Cooperative with Botany).
Ration Experiments with Lambs. State funds.
Cornfield Lamb-feeding Experiment. State funds.
Summer-fallow Experiment at Akron, Colo. State funds.
Winter Maintenance of Breeding Ewes. State funds.
Poultry Experiments. State funds.
Beet By-products for Fattening Beef Calves. Purnell fund.
Comparative Value of Different Kinds of Molasses in Lamb-fattening Rations. Purnell and State funds.
Hog Feeding in the San Luis Valley. State funds.
Utilization of Dryland Feeds. State funds.

Bacteriology Section

Heat-resisting Bacteria in Fresh and Canned Vegetables. Adams fund.
Value of Certain Carbon Compounds as Sources of Energy for Azotobacter. Adams fund.
Natural Innoculation of Colorado Soils with Legume Bacteria. Hatch and State funds.
Winogradsky Method of Testing Soil Deficiencies. Purnell fund.
Control of Excessive Soil Nitrates in the Arkansas Valley. Purnell and State funds. (Cooperative with Agronomy).
Studies in the Control of Bacterial Wilt and Winter Killing. Purnell and State funds. (Cooperative with Agronomy).

Botany Section

Range and Pasture Improvement. Purnell and State funds. (Cooperative with Animal Investigations).
Cereal and Field-crop Disease Studies. Hatch and State funds.
Truck-crop Disease Studies. Hatch and State funds.
Weed Control. Purnell and State funds.
Indentification of Species of Beta and Brassica. Purnell fund.

Chemistry Section

Deterioration of Hays Resulting from Rain. Adams, Hatch and State funds.

Entomology Section

Plant-louse Investigations. Adams fund.
Ants in Relation to Plant Lice. Hatch and State funds.
Codling-moth Studies. Hatch and State funds.

Codling-moth Control by Means of an Egg Parasite. Purnell and State funds.
Grasshopper Control. State funds.
Potato Flea-Beetle. State funds.
General Insect Investigations. State funds.
Rodent Poisoning. State funds.
Rodent Life Habits. State funds.
Colorado Insect Fauna. State funds.
Resistance of Bees to American Foulbrood. State funds.
Relation of the Honey Bee to the Production of Seed in Red Clover. State funds.
Range Insects. State funds.

Economics and Sociology Section

An Economic Study of the Peach Industry in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.
An Economic Study of Farm Organization and Management in the Greeley area in Northeastern Colorado. Purnell fund.
A Study of Costs and Methods of Producing Cattle and Sheep on the Range in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.
A Study of the Social Status of the Spanish-speaking People in Rural Colorado. Purnell fund.
A Study of Taxation in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.
A Study of the Methods of Storage and Marketing Practices which obtain in handling Potatoes on Farms in the San Luis Valley. State funds. In cooperation with Colorado Division of Markets.
An Economic Study of the Apple Industry of Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.
An Economic Study of Land Utilization in Northwestern Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.
A Study of the Major Types of Cooperative Organizations of Associations in Colorado. Purnell fund. In cooperation with U. S. Dept. of Agriculture.

Home Economics Section

The Baking of Flour Mixtures at High Altitudes. Part II. Purnell fund.

Horticultural Section

Potato-variety Testing and Improvement by Selection. Hatch and State funds.
Garden-pea Variety and Breeding. Purnell and State funds.

Spanish Onion Breeding Work. Purnell and State funds.
Development of a Tipburn-resistant Variety of Head Lettuce. Purnell fund.
High-altitude Vegetable Production. State funds.
Orchard Management including Cover Crops. State funds.
Raspberry Investigations. State funds.
Small Fruits. State funds.
Certified Seed Potatoes. State funds.

Irrigation Investigations Section

Measurement of Water. Hatch and State funds.
Evaporation. Hatch and State funds.
(a) From a Free Water Surface.
(b) From Moist Soils.
Meteorology. State funds.
Pumping for Irrigation and Drainage. State funds.

Pathology Section

Sheep Losses in Feedlots. Hatch fund.
Contagious Abortion. Hatch and State funds.
Coccidiosis in Cattle. Purnell fund.
Death Losses in Lambs on Heavy Grain Feed. Purnell and State funds.
Icterohematuria. State funds.
General Disease Investigations. State funds.

Veterinary Section

Animal Diseases. State funds.

ENGINEERING DIVISION

Civil Engineering Section

Frost Heaving Investigation on Concrete Slabs. State funds.
Pavement Cores and Subgrade. State funds.
Light Asphaltic Road Surfaces. State funds.
Road Materials of Colorado. State funds.
Road Oils. State funds.

Mechanical Engineering Section

No active projects. Work in abeyance during past 7 months.

Following are brief reports from the heads of sections concerning the work of the past months.

Respectfully submitted,
C. P. GILLETTE, Director

REPORT OF THE AGRONOMIST

To the Director:

I am submitting my annual report for the fiscal year ending June 30, 1930.

The staff of the Agronomy Section has consisted of: Alvin Kezer, chief; D. W. Robertson, associate; G. Warren Deming, assistant; R. D. Hockensmith, assistant and Warren H. Leonard, assistant. Mr. Robert Robertson and Mr. Deming are full-time research workers. Mr. Hockensmith and Mr. Leonard are primarily teachers but render valuable assistance on the research problems. I should not neglect to mention Mr. John W. Sjogren; while he has not been officially on the experimental staff, he has been a constant producer. One bulletin has come from his work during the present year and nearly enough material for another bulletin has been collected. All of these workers are stationed at the home plant.

Mr. Adams is still in charge at Cheyenne Wells. Mr. Robert Gardner is in charge at Rocky Ford and Mr. Dwight Koonce is at Fort Lewis.

At Fort Collins, the work of the year has been a continuation of the critical period, residual effect of irrigation water, improved seed, methods of determining fertilizer needs, alfalfa-disease control, and other minor projects. Work on two new projects, each in cooperation with the United States Department of Agriculture, is under way—one at Rocky Ford on the clover crop and one on sugar beets, work on which will be located both at Rocky Ford and Fort Collins.

Under the improved-seed project, we are carrying on variety tests of cereals, pasture crops and a large portion of our breeding work. We hope during this coming year to complete the test of pasture crops and pasture mixtures so far as determining the adaptability of varieties to our climatic conditions and their growth behaviour with irrigation can determine their value. We have tried mowing the plats frequently to imitate the grazing of animals. We appreciate that such frequent mowing is not exactly the same as animal grazing but it does give us an idea of the behaviour of the different crops. We believe that we have carried these tests long enough to establish which are the better adapted varieties and which are the better adapted mixtures. We have also learned considerably about the seeding and care of such crops. The next procedure on irrigated pastures, it seems to us, is the actual grazing of some of these different mixtures to determine the effect of the tramping and selective biting of animals.

We need to do with dryland crops a greater amount of work than we are now doing to try to find the best adapted dryland mixtures. So far, we do not know of any tame grasses adapted generally to our dry uplands. Our present pasture possibilities under cultivation on the dry uplands are annual pastures.

We have carried a very large amount of small-grain selection and hybridization work. From some of this work we have gained some new genetic facts, both on wheat and barley. The hybrid work has given rise to one publication during the year and another paper has been accepted for publication. Hybrid work is somewhat slow in producing new and valuable varieties. We have promising selections coming on in our hybrid progenies. With the wheats and barleys, especially, we take certain of these hybrids to Akron yearly to let the most severe climatic and soil conditions exercise selection. Each year, we have about 1,000 of such progenies which we take to Akron.

The methods-of-measuring-soil-fertility project is carried on in cooperation with the Bacteriology Section. We can report progress on this project. In all cases in 1929, field applications of fertilizer gave field results in perfect accord with the laboratory predictions based upon laboratory tests. The field program has been somewhat enlarged this year by phases along the same lines as previously reported.

The alfalfa-disease control project, also in cooperation with the Bacteriology Section, is being vigorously pushed. We have nearly 20 acres of plats, testing both varieties and fertilizer-application methods upon the Agronomy farm. We also have plantings of promising resistant varieties in fields on farms in Larimer, Boulder and Weld counties. These farm fields were selected because they were known to be in regions where alfalfa wilt had destroyed previous alfalfa crops. The need for this work is growing because 1930 has seen an increase in the loss area. Considerable winter killing and disease killing has taken place in Morgan, Logan and Sedgwick counties in Northeastern Colorado and in Crowley, Otero, Bent and Prowers counties in Southeastern Colorado. The department has been making trips into these regions and assisting farmers in every way possible to improve their alfalfa crop conditions.

This year, we have taken up two new major projects. One is on clover investigations which is being conducted in cooperation with the Forage Office of the United States Department of Agriculture. Most of the work on this project will be conducted in the Arkansas Valley. Observations will be made in other localities. The other project is on sugar-beet-investigations, in cooperation with the Sugar Office of the United States Department of Agriculture. This work is being carried on both at Fort Collins and at Rocky Ford. At Fort Collins the work is requiring the use of about 60 acres of land in 1930. A part of this land is rented by the government from the County Farm to the east of our own experimental farm. A part of it is on our own experiment station farm and a part is located upon the lands of private farmers because we can get their conditions which we do not have upon either of these farms. At Rocky Ford, the project has available 40 acres of land—all of this is in use, but not all in sugar beets as a rotation must be followed in order to keep down nematode and other beet diseases.

These experiments are covering tests in a large number of methods, of planting methods, of thinning methods, of cultivating methods, of irrigation methods and a complete series of fertility tests.

The work at Akron is concentrated on the rate and date of planting, small grains, corn, forage crops, forage-crop varieties and cultural tests, and rotation and tillage-method tests. So far, in the variety tests of wheat, Kanred has proved superior for a series of years altho some other sorts of the Crimean or Turkey group are close contenders. The winter of 1929-30 was unusually severe. Accordingly, some of the less hardy of the winter types such as Blackhull have been severely damaged by winter killing. Such winters bring out the superiority of the Kanred, Karkov and Standard Turkey group.

New barleys upon which we reported last year are being increased for distribution to farmers. The best adapted dryland strains are Club Mariout, a selection from White Smyrna and Flinn. All of these are narrow-leafed barleys. When it is realized that one year with another, barley will produce as much feed grain per acre as corn, one realizes the importance of this crop in our dryland economy, as it can be handled readily and cheaply with tractor-drawn implements, thru requiring only a very small amount of hand labor.

We believe we have sufficient data on hog millet to publish an information bulletin this season. The feeding experiment with hog millet has brought out an unusual demand for this crop. I think it is unfortunate that it was called Hershey in some of our feeding publications. Hershey happens to be the name applied locally in two or three of our Northeastern counties. Everywhere else it is known as hog millet or proso. The use of this name was unfortunate because it has made farmers, agricultural writers and others unfamiliar with the crop, believe that we have here an absolutely new crop.

The cooperative studies on nitrate control at Rocky Ford have been conducted under the immediate charge of Mr. Robert Gardner. If this year's results turn out favorably and of the same order as for the past several years, we hope to publish on a number of phases of this work. The program at Rocky Ford has been enlarged to include clover investigations.

High-altitude agriculture is the main work being conducted at Fort Lewis. Our present studies there consist in variety, cultural and irrigation practice work with grains, pasture, meadow and forage crops.

Data from Fort Lewis have already appeared in one bulletin and further data will be used in forthcoming bulletins which are now being prepared to offer for publication.

The Cheyenne Wells work is of necessity being carried simply on a rental basis as we have no appropriation to support the work. We have supplied Mr. Adams with some cherries, plums, ornamental

trees, brambles and some shrubbery to assist in keeping the place up. Cheyenne Wells is making an excellent demonstration but cannot contribute in a research way without better financing.

We are serving the dryland needs thru cooperative arrangements with the Office of Dry Land Agriculture, United States Department of Agriculture at Akron. Akron being further north in the state and higher in altitude, does not permit studies on many of the sorghums and other crops adapted to regions further south and east in the dryland area. The dryland area contributes much more to our agriculture than is ordinarily recognized. Over 70 percent of the wheat production, about 80 percent of the corn and around 70 percent of the barley are grown upon our drylands. Millets, sorghums—both grain and forage—are practically confined to the drylands. In addition, judicious production of feeds and forage crops enables large numbers of livestock to be grown and matured. The needs of this great region justify more attention and heavier financing than we have been able to give.

The picture of agricultural practices on the plains has changed markedly in the past few years. Horses are being used less and less. Tractors are increasing in reliability and in use. Consequently, tractor-drawn and tractor-operated implements are quite generally replacing horse-drawn implements. We need to know not only relative costs of horse and tractor operations but we need to be making studies on the better methods of using tractor-drawn implements. The used of the tractor is making possible the very great enlargement of the area which a single man can cultivate. Heretofore with horses, the amount of land a grower could prepare for seeding and the amount that he could harvest constituted his limits. With tractor-drawn implements, the same limitations hold. But, with tractor-drawn implements both the seeding and harvesting area can be enormously increased. Tractors do not have to stop to rest for by shift in operators they can be worked 24 hours a day. Thus, much larger areas can be prepared for seeding and can be seeded than was possible with horse-drawn or animal-drawn implements. At harvest time the introduction of the combine, tractor-drawn and tractor-operated, with the introduction of the truck for the delivery of the product, enormously increases the amount a given number of persons can harvest. Methods of best using such equipment should be investigated. We should be able to supply farmers this information instead of having farmers subjected to the necessity of each individual working out all of the problems connected with such power use.

Our laboratories during the year have been considerably strengthened so that we are in much better position to do certain technical operations and soil studies. Many of our people have felt that our soils, being new, were inexhaustible in fertility. Fifteen or even 10 years ago commercial fertilizers in general gave no returns. But, at the present time in the older irrigated regions, phosphate fertilizers

are giving returns on better than 70 percent of the lands. This is simply a fore-runner of what we are facing in soil problems. These problems comprise problems of fertility, problems of management in connection with the use of irrigation water, problems of fertility in relation to types of minerals in composition. All of these and many others are presenting new phases which have an influence on the production of crops. We cannot expect to solve all of these but we are equipped to make a start.

I am pleased to say that in Mr. Robert Gardner and in Mr. Roy D. Hockensmith, we have two well-trained young men whom we are starting on these problems.

Respectfully submitted,
ALVIN KEZER, Agronomist.

REPORT OF THE ANIMAL HUSBANDMAN

To the Director:

Following is a report upon the various projects carried by this section:

Experiments conducted between Dec. 1, 1929 and May 15, 1930

Ration Experiments With Cattle.—E. J. Maynard, Geo. E. Morton and H. B. Osland.—Six lots of steer calves were fattened during a 185-day winter feeding period. A study was made of the comparative feeding value of wet beet pulp, corn silage, cull potatoes and a silage composed of a mixture of cull potatoes and dry corn fodder cut together into the silo. In certain years a surplus of potatoes at low prices may find a large supply of culls and markets held into the spring of the year on the farm. Tests at the station indicate that these potatoes, with some dry filler included, may be cut into the silo (which is usually empty at this time of year) and may be safely carried thru the summer for feeding operations the following fall and winter. A basal ration consisting of ground barley, cottonseed cake and alfalfa hay has been used in this experiment. This is the first test of the current series. In connection with this work a study was made of the comparative shrinkage of pressed beet pulp when stored in an open pile, in a trench silo and in a straw silo.

Summer Fattening Experiment With Cattle.—Geo. E. Morton and E. J. Maynard.—Beef calves were fed thru the winter largely on available roughages with a limited amount of concentrates in order that they might be in fleshy condition for a quick finish with grain on irrigated pastures during the summer. A comparison of corn silage and composted beet tops was made during the winter feeding period, each being fed along with ground barley, cottonseed cake, wet beet

pulp and alfalfa hay. The cattle will be finished for an early fall market on irrigated pastures of alfalfa and Morton's pasture grass mixture with and without a concentrated protein supplement.

Rations for Fattening Lambs.—E. J. Maynard and H. B. Osland.—A comparison was made between cull potatoes, cull-potato-and-corn-fodder silage and siloed beet pulp fed as supplements to basal rations of whole barley and alfalfa hay and whole barley and alfalfa hay and cottonseed meal for fattening lambs. Alfalfa meal (13 percent protein) and alfalfa stem meal (9 percent protein) were compared in a self-fed mixture of ground barley, cottonseed meal, molasses and alfalfa.

Field Lamb Feeding.—E. J. Maynard and H. B. Osland.—Lambs were pasture on stock beets for 43 days during the fall. During this period they were fed alfalfa hay in drylot at night and one lot received whole barley while the other lot got no grain. A check lot was fed whole barley and alfalfa hay in drylot. All lots were finished during a 70-day period on a standard ration of barley, wet beet pulp, cottonseed meal and alfalfa. The stock beets yielded 15.26 tons per acre. The final feed costs were lowest for the lambs fattened in drylot. A study of comparative yields of blocked and unblocked stock beets is being made in cooperation with the Agronomy Department.

Range Management.—E. J. Maynard and H. B. Osland.—A study of early spring protection to forage and rotation of cattle between two pastures as factors affecting vitality and increased production of forage plants on low foothill range of Northern Colorado; to compare effects of no protection to forage, early protection to forage and early protection plus rotation by grazing regulation of cattle; to study winter maintenance rations and general management problems.

Summer Fallow Experiment With Sheep at Akron.—Geo. E. Morton, E. J. Maynard and J. F. Brandon.—A study of sheep maintenance on dryland farms. The grazing of weed growth on summer fallow and consequent labor reduction for summer tillage. A study of the carrying capacity of weed growth on summer fallow and stubble land and of rye pasture and native sod. A 10-year period (1920 to 1930) has been completed in this work.

Utilization of Dry Land Feeds.—Geo. E. Morton, E. J. Maynard and J. F. Brandon.—(a) Winter Hog Feeding.—A comparison of the fattening grains; corn, barley and proso or hog millet, fed singly and in combinations along with a standard protein supplement. A comparison of different protein supplements and protein supplement vs. no protein supplement.

(b) Winter Lamb Feeding.—A comparison of corn, proso or hog millet and a combination of the two fed with sorgho fodder and a protein supplement to fattening lambs. A comparison of protein supplements for fattening lambs in non-irrigated sections. Ground vs. unground millet for fattening lambs.

(c) Summer Hog Feeding.—Summer fattening tests with hogs on a succession of annuals (fall-sown rye, spring-sown barley and sudan grass) along with grain and a protein supplement.

(d) Pastures for Non-irrigated Sections.—Some tests with sweet clover both as a pasture and as a hay crop have been made. A perennial dryland mixture has been grown.

Fattening Hogs in Peafield in the San Luis Valley.—H. B. Osland and E. J. Maynard.—A study of the value of different protein and carbonaceous supplements including tankage, skimmilk, alfalfa meal and barley fed to hogs pastured in peafields in the San Luis Valley. Preliminary work in an attempt to determine the most efficient supplements with which to balance peas pastured in the field.

Maintenance of Ewes.—B. W. Fairbanks.—The second year's work on the ewe-maintenance experiment under its present setup was completed at noon on May 5. All figures have been collected and compilation will take place as soon as the opportunity presents itself, which will no doubt be immediately after vacation. At that time we can check the work and come to a definite decision as to whether the experiment should be completed with 2 year's work or whether a third year is advisable.

All-Mash vs. Mash-and-Scratch Laying Rations.—C. N. Keen.—Two lots of birds were put on rations, lot 1 on all-mash ration, and lot 2 a mash-and-scratch ration. The number in each lot was 67 birds. Comparison of the two methods of feeding has been made to find the result upon laying, the condition of the birds and the cost of each method.

Advanced Registry Testing.—B. W. Fairbanks.—Following is a summary of the work done since May 1, 1929:

Month	1-Day	2-Day	7-Day	Fees
May	16	45		$15.25
June	15	45	3	18.00
July	19	51	6	23.50
August	20	51	2	19.75
September	20	46	4	20.50
October	22	38	5	20.00
November	18	42	1	16.00
December	18	39	3	17.25
January	38	21		14.75
February	47	5		13.00
March	75	7	1	17.75
April	59	3		15.50
	367	393	25	$211.25

Respectfully submitted,

GEO. E. MORTON, Animal Husbandman.

REPORT OF BACTERIOLOGIST

To the Director:

I have the honor to submit herewith the report of the Bacteriological Section of the Experiment Station for the period December 1, 1929 to May 31, 1930.

A complete summary of our work up to December 1, 1929, covering the first half of the new fiscal year, was presented as a part of my annual report for 1929, and, accordingly, the present statement pertains only to the activities of this section for the past 6 months.

At this time, I desire to call your attention to three lines of investigation which we have been conducting:

1. Alfalfa Wilt-Resistance Tests.
2. Winogradsky Soil-Deficiency Tests.
3. Niter Studies at Rocky Ford.

Alfalfa Wilt.—While it is a little early to predict the losses from this disease this year, it may be a matter of interest to note that the wilt is already making its appearance in the old stands.

Our variety tests in Boulder, Larimer and Weld counties came thru the winter in excellent condition in spite of the severe cold weather. The outstanding difference to be observed at this time among the several varieties under study is the marked susceptibility of the Common strain to mildew. The yellow foliage, resulting from this disease, is so conspicuous that the plots planted to Common can be distinguished easily from the other varieties at a considerable distance. The same susceptibility, but to a lesser degree, exists in the Argentine. The stands are now 1 year old, and while to date none of the varieties shows wilt, there appears to have been dying out during the winter by Hardigan, Canadian Variegated and Ladak. From the standpoint of growth and vigor, the Canadian Variegated looks very promising; the Cossack and Grimm are close seconds; the Ladak is thrifty but appears to be more of a prostrate than an erect type; Hardigan, Argentine and Utah Common are also included in the test.

Winogradsky Soil Tests.—Owing to the fact that this test requires only 72 hours, we have been able to furnish many farmers with information on their fertilizer needs in time for spring planting. Since March 1, we have examined soil from 214 fields and orchards, and the samples are still coming in. This has meant nearly 2,000 tests. While it has taxed our laboratory force to the limit to keep up with these, we have been able to get returns to the farmers in less than 10 days after the receipt of the samples. To help defray the expense of the work, a nominal charge of 50 cents per sample has been made. Altho this

does not begin to pay for the actual cost of making the tests, it helps and also serves as a deterrent to the idle curious. The bacterial soil plaque is used in determining the phosphate and potash deficiencies, but chemical methods are employed for the nitrate, lime and acid analyses.

The results of the tests are reported on a card and tell the grower if his soil needs potash, phosphate, nitrate or lime, and if it is too acid. It also carries a recommendation for treating the soil based upon these results. One copy of this card is kept in the laboratory files, a second is sent to the farmer, and a third goes to the county agent. The form we use follows:

SOIL FERTILITY TEST
(Farmer's Card)

Name .... Address ....
Sample No. .... Date ....

RESULT OF THE TEST

Phosphate .... Lime ....
Potash .... Acid ....
Nitrate .... Basic ....
Recommended Application ....
....
....
Past History ....
....
Present Crop ....

The results from 196 soils examined this spring show 74 percent to be deficient in phosphate, 3 percent in potash, 17 percent in nitrate and 21 percent in lime; 15 percent are slightly acid, 76 percent basic and 9 percent neutral.

By way of checking our laboratory results, we have put out five test plots. Four of these are planted to sugar beets and one to barley. In this work we are endeavoring to determine the relative value of different amounts and kinds of phosphate for producing the maximum yield of sugar beets and the value of phosphate alone and in combination with ammonium sulfate for barley and alfalfa.

Dr. D. W. Robertson of the Agronomy Section is cooperating in this work.

Niter Studies.—The beneficial effect of different crop residues and sawdust in controlling the formation of excessive soil nitrates has been so striking that we have continued this line another season. In the past this series of plots has been kept fallow. This year they will be planted to a crop in order to determine the effect of the residue treatment on crop production. If this method of handling these high niter soils proves as effective as our laboratory tests indicate, we shall have found a very simple and practicable solution for the difficulty.

Our soil-nitrate determinations, made over a period of 6 years and now numbering more than 20,000, have proved conclusively that there is a marked increase and accumulation of nitrates under cultivated crops during the growing season which reaches its peak early in August. It has been our contention, and still is, that these nitrates owe their origin to the oxidation of the organic nitrogen contained in Azotobacter cells which in turn have obtained this element from the air by the fixation of atmospheric nitrogen. In order to make our theory absolutely conclusive, we are making determinations of the organic nitrogen this season in addition to the nitrate. We expect to be able to show by this that the curve for the organic nitrogen follows much the same course as that of the nitrate, except that the former reaches its peak somewhat in advance of the latter.

Miscellaneous

1. **Bacterial Blight of Beans.**—Bacteriosis or bacterial blight is unquestionably the most serious disease of beans in Colorado. This year we are carrying on resistance tests at Rocky Ford with six varieties obtained from the U. S. Department of Agriculture thru the courtesy of Dr. Zaumeyer. These beans, under eastern conditions, have shown more or less freedom from blight and we are hopeful that they will exhibit the same resistance here.

2. **Extension Service.**—At the invitation of the Extension Service, I gave one radio talk over Station KOA on alfalfa failures. In January, I gave six lectures on soil questions in connection with soil schools which were held at Fruita and Grand Junction; at this time I gave two additional talks on Tularemia and Food Poisoning before the Fruita High School and Fruita Extension Women's Club respectively.

An exhibit illustrating our work in testing soils for fertilizer needs was prepared for the Weld County Farmers Institute held in Greeley in January. At this time I described the use of the soil plaque and discussed our soil deficiencies.

At the National Western Stock Show, held in Denver in January, we set up a laboratory for making soil tests and demonstrated our work with the soil plaque in determining soil deficiencies. In a second booth,

we showed graphically the fertilizer needs of our common crops and exhibited a large assortment of commercial fertilizers. In connection with this, we featured the manufacture of treble superphosphate.

3. College Instruction.—At the invitation of the Horticultural Department, I gave lectures on vinegar making and soil fertility before the horticultural classes; a similar lecture on soil bacteriology was given before the class in industrial chemistry.

4. Swimming Pools.—With the installation of liquid chlorine as the purifying agent in the women's swimming pool, it has become necessary to make daily tests of the water for residual chlorine and acidity. The purity of the pool has been faultless under this treatment. The present system of circulating the chlorinated water before it enters the pool is not satisfactory since all of the water enters at one end thereby producing too great a concentration of chlorine at that point. Some method of introducing part of the water at the north end should be worked out in order to give more uniform distribution of the chlorine.

We have continued the weekly examination of the men's pool and have found the quality to be satisfactory with the violet-ray purification with the exception of the times when the pool is overloaded, as is the case during high-school meets.

5. Laboratory Needs.—As the scope of our work broadens and the volume of our routine increases, we feel greatly the need of larger quarters. We should have additional library and office space, separate laboratories for individual research and a laboratory for biochemistry. It is to be hoped that in the next building program, some provision will be made for enlarging the Horticultural Building so as to take care of this much needed expansion.

In the various phases of the work reported here, I have been assisted by Miss Laura C. Stewart, Mr. Robert Gardner, Dr. D. W. Robertson, Mrs. Mildred Brown Carpenter, Mrs. Alpha Powell Head and Miss Esther Elliott, whose efficient services I am pleased to acknowledge.

In conclusion, I desire to express my very great appreciation of the opportunity afforded me of attending the eleventh annual meeting of the Southwest Division of the American Association for the Advancement of Science held at Tucson, Arizona, April 21 to 25, 1930, and for the honor of representing the college at the inauguration of President Shantz.

To the Director I am very grateful for his continued interest in the welfare of the Bacteriological Section and for the support he has given our work.

Respectfully submitted,
WALTER G. SACKETT, Bacteriologist.

REPORT OF THE BOTANIST

To the Director:

I beg to submit the following report of the work carried by the Botanical section for the past fiscal year.

Range and Pasture Improvement.—Study is being made of reseeding, of the results of continuous and deferred grazing, of the effect of soil and climatic conditions, also the results of early pasturing, trampling and poisonous plants.

The following are phases of range improvement being investigated:

1. Carrying capacity of grama-buffalo grass vegetation for sheep.—This study is being carried on cooperatively with the Animal Husbandry department at the U. S. D. A. Field Station. The data covering the entire period of experimentation is being prepared for publication.

2. Ecology and improvement of mixed prairie cattle range at an altitude of 5,000 feet, Ft. Collins.—Along the base of the eastern foothills is found a type of vegetation composed of a great variety of grasses and weeds. The dominant grasses are *Stipa* spp., *Agropyron Smithii, Bouteloua gracilis,* and *Bulbilis dactyloides.* A thoro study of this type of vegetation in relation to grazing practice is being made. The Department of Animal Husbandry is cooperating in this thru feeding experiments. Data covering 9 years' study of this range are being prepared for publication.

3. Improvement and management of upper foothill cattle range at an altitude of 7,000 feet near Virginia Dale.—Areas plowed up by homesteaders and then abandoned have been greatly improved by seeding to smooth brome grass, slender wheatgrass, crested wheatgrass and yellow sweet clover. A vegetation map is being prepared as a basis for evolving the best management plans of such regions.

Basic ecologic data are being gathered to aid in solving problems such as eradication of poisonous plants, prevention of erosion, determination of proper carrying capacity, and other phases of range improvement and management.

4. Improvement of sagebrush (*Artemisia tridentata*) range.—This study has been conducted in the Laramie River Valley for 3 years. Four-to-eight-fold increase in forage has been secured in this time due to natural revegetation following burning. The damage done by rodents has been shown to be very great. This work is now being extended to North Park where a comprehensive experiment and demonstration has been laid out in cooperation with the Extension Service.

5. Succession and competition of plants in irrigated pastures in relation to pasture management.—A number of different seed mixtures and the resulting pasture stands each year following seeding have been analyzed. Part of this study is in cooperation with the Department of Agronomy. These pastures are under a great variety of soils and treatment. A large amount of data on the habits of plants, especially in regard to competition and succession, has been gathered. This information is valuable in deciding the proper mixture to sow as well as in the management of the pasture.

Weed Control.—The weed-control work is centered around the study of chlorate sprays under Colorado conditions and some of the physiology involved in their use. They are now being tried on bindweed, poverty weeds, Canada thistle, Russian knapweed, perennial peppergrass, larkspur, seedling barberries and willow. A brief study is also being made of various chemical treatments for dandelions.

Truck-Crop Diseases.—During the past year, study has been made of onion diseases in the Arkansas Valley. A substation has been established there during the summer for following the development of neck rot and purple blotch.

Cereal Diseases.—Studies on stinking smut of wheat have been continued. Work on infection has been accepted for publication. Other physiological studies are prepared for publication.

Observations and study of the foot rot of wheat are being continued. This disease made its appearance in 1928 and again in 1930 following severe winter with little snow.

Cooperative Work.—In cooperation with the office of Cereal Crops and Diseases, U. S. D. A., work on barberry eradication has continued.

The Office of Sugar Crops, during the past year, established cooperative work with the Botanical Section in studying sugar-beet diseases.

Miscellaneous pieces of work have been carried on in addition to the above formal projects. Reports of these studies are indicated in the bibliography of Botanical Publications here attached.

Seed Testing Work

For the fiscal year beginning July 1, 1929.
Report of Seed Samples Tested

	Purity	Germination	Examination	Identification
Current samples	1357	3201	7	31
Certification service	168	386		
Inspection samples	651	985		
Sugar-beet investigations		27		
Wild-oat study		120		
Longevity studies		113		
Other investigations	57	150		
Total samples	2233	4982		

All samples of peas and beans have been checked by greenhouse tests.

Numerous samples of cereals which were found to be dormant when tested by the usual methods, were tested at low temperatures to test the degree of dormancy.

All samples exhibiting unusual or unsatisfactory behavior when tested by the method suitable to the species, have been retested in daylight, in sand, soil, greenhouse or by several of these methods.

1929-1930 Publications of the Botanical Department

Durrell, L. W. A new Pathology Text (review)
Principles of plant pathology by Charles E. Owens.
Phytopathology. 19:177.

Hanson, Herbert C. Range Resources of the San Luis Valley.
Colo. Agr. Exp. Sta. Bul. 335:1-60.

———— Grazing Types in Colorado.
The Cattleman 15:57-63 (April)

———— Reseeding Waste Range Land.
The Cattleman 15:31 (May)

———— Intensity of Grazing in Relation to Proximity to Isolation Transects. Ecology 10:343-346.

———— Analysis of Seeding Mixtures and Resulting Stands in Irrigated Pastures of Northern Colorado.
Journal Am. Soc. Agronomy 21:650-659.

———— Discussion on "Eradication of Brush and Weeds from Pasture" by A. E. Aldous. Jr. Am. Soc. Agronomy 21:666.

———— Pasture Plants for Sheep.
American Sheep Breeder, July.

———— With F. E. Clements and J. E. Weaver
Plant Competition. Carnegie Inst. Publ. No. 398.

———— The struggle for existence among Range Plants.
The Producer. 11:5-7.

———— Grazing Types in Colorado.
The Cattleman 15:57 (March)

———— Ecological Bases for Grazing Studies.
Abstract Published in Journal of Colorado-Wyoming Academy of Science. Vol. 1.

———— Pasture Plants for Sheep.
American Sheep Breeder, July.

———— Reseeding, Range Lands.
The Natl. Wool Grower, October.

———— Improvement of Sagebrush Range in Colorado.
Colo. Agr. Exp. Sta. Bul. 356.

———— Importance of Western Grazing Land.
The Cattleman, March.

LeClerg, E. L. Some Common Diseases of Ornamental Plants. Colo. Sta. Bul. 351.

LeClerg, E. L. Neck Rot of Onions. Colo. Agr. Exp. Sta. Bul. 301.

Rogers, Charles F. Canada Thistle and Russian Knapweed and their Control. Colo. Agr. Exp. Sta. Bul. 348.

Smith, E. C. Some Phases of Spore Germination of Myxomycetes. Amer. Jr. Bot. 16:645-50.

———— Longevity of Spores of Myxomycetes.

Journal Colorado-Wyoming Academy of Science Vol. I No. 2.

LeClerg, E. L. Observations on Some Onion Diseases of Colorado.

Ashton, Ruth E. Preliminary Observations on Revegetation of the Twin Sisters Burn in Rocky Mountain National Park.

Smith, E. C. The Longevity of Myxomycete Spores.

Hanson, Herbert C. Improvement of Sagebrush Range in Colorado.

Smith, E. C. Trametes Peckii, a Destructive Parasite in Apple Orchards.

Love, L. Dudley and Herbert C. Hanson. Relation of Environment Factor Data to Range Management.

Bodine, E. W. The Effect of H-ion Concentration Upon Spore Germination and Growth of *Tilletia laevis* (Kuhn.)

——— Method of Culturing and the Growth of *Tilletia laevis.* (Kuhn.) on media.

Lungren, E. A. Progress of Barberry Eradication and Black Stem Rust Investigation in Colorado.

Hatfield, Ira and Charles F. Rogers. A Chemical Indicator for the Diffusion of Carbon Disulfide Through the Soil.

Submitted or in Press.

LeClerg, E. L. Cultural Studies of Some Soil Fungi, Soil Science.

Hatfield, Ira and Charles F. Rogers. Formula and Apparatus for Measuring the Liquid-to-Gas Volume Change, Plant Physiology.

Rogers, Charles F. and Ira Hatfield. A Chemical Indicator for Testing in the Field the Diffusion of Carbon Disulfide Gas Through the Soil, Plant Physiology.

Publications Submitted or in Press.

Durrell, L. W. Diseases of Corn.
Symposium, Botanical Society of America, A. A. A. S.

Bodine, E. W. and L. W. Durrell.
Inoculation of Wheat with *Tilletia laevis.* Phytopathology.

Howe, Mary F. Germination and Infection with *Sclerospora graminicola.* Abst. Mycologia.

Lute, Anna M. Distinction between Seeds of White and Yellow Blossom Sweet Clover in Mixture. Proc. A. O. S. A.

Lyon, Mildred E. and Albina F. Musel. A Direct Method of Testing Seed. Proc. A. O. S. A.

Hanson, Herbert C. and L. Dudley Love. A Comparison of Methods of Quadratting. Ecology.

——— Pastures for Spring and Fall Grazing in Mountains of Colorado.

——— Improvement of Grazing Lands.
The Forester.

———— Range Reseeding. The Producer.

———— and Richard V. Lott. Root Systems of Strawberry Varieties Under Irrigation at Fort Collins, Colorado.

LeClerg, E. L. Onion Diseases of Colorado.

Smith, E. C. Ecological Observations on Colorado Myxomycetes. Myc. Section, Am. Bot. Society.

———— Trametes Hispida, a Destructive Parasite in Colorado Apple Orchards. Mycologia.

Respectfully submitted,

L. W. DURRELL, Botanist.

REPORT OF THE CHEMIST

To the Director:

During the time covered by this report, this section has finished the project entitled "Sources of carbon dioxid in soils cropped to alfalfa or clover and its relation to soil changes and plant growth."

This project was extended in order to follow the development of the carbon dioxid in the soil during the first year after these crops had been plowed under. The whole series of plots, fallow as well as cropped, was studied.

A small section, representing the whole series, was planted to wheat the spring after the crops were plowed under, but the rest of the land was fallowed in order to follow the carbon dioxid. The results of these experiments have not yet been published. The manuscripts are now in your hand.

The results of our observations on the amounts and distribution of the carbon dioxid, present too many features to permit presentation in this report, but the crops obtained the first year after alfalfa and clover were instructive. The seeding was at the rate of 90 pounds per acre. After the alfalfa, the wheat grew rank and tillered freely but the grain was shrunken and the yield the smallest of the four plats which stood in the following order: After fallow 58 bushels, after corn 56, after clover 46, after alfalfa 40.

The protein content after alfalfa, 19 percent, after fallow, 17.25, after clover, 17.5, after corn, 12.75.

The succeeding year, 1929, the whole piece was planted to wheat, the same variety as in 1928, but the seeding was made 40 pounds to the

acre instead of 90 because we surmised that the tillering and rank growth after alfalfa might be the cause of the relatively adverse results after alfalfa. The growth in 1929 did not show the differences observed in 1928, but was very good and uniform and the yields satisfactory, but the alfalfa plots fell below the fallow by 5 bushels, probably not a significant difference.

We made a small experiment with ground rock phosphate, superphosphate and gypsum. The gypsum was used, not because there is any lack of it in this soil, but to get an idea of the effect of the gypsum in the superphosphate, if it had any.

Of these three, gypsum alone produced an evident effect on the growth of the plants and gave the highest yield obtained, 57.5 bushels. All other details of this project will be given in the bulletins presenting the results obtained in this study.

The project being studied at the present time is "the deterioration of alfalfa hay due to wetting by rain in the field while curing." This project will not be completed until the samples of 1930 have been studied.

This project was undertaken because there seems to be but little positively known about the subject, and the facts given in Bulletin 35 of this station, published 34 years ago, seem to be but little known.

Some statements made in Bulletin 35 are reproduced in the following:

"The total rainfall between May 28th and June 12th, the respective dates of cutting and putting into the mow, was 1.76 inches. The weather during this time ranged from 72 to 81 degrees. Any calculations based upon the above (analysis) without further data would evidently be liable to lead to erroneous conclusions, but it suffices to show that the popular estimate of the value of such hay is not far from correct; i. e., about one-half that of good hay. The damage is not simply the amounts of proteids and nitrogen-free extract (carbohydrates) lost, but also the loss of those general qualities recognized as essential to good hay."

The whole subject of vitamins has been developed since these sentences were written, and these must be taken into consideration. Feeding experiments with white rats are being made to establish the loss of these factors, which seems to be very large indeed.

The details of this study are too extensive to properly find place in a general report.

Respectfully submitted,

WM. P. HEADDEN, Chemist.

REPORT OF THE AGRICULTURAL ECONOMIST

To the Director:

During the year ending June 30, 1930, the Section of Agricultural Economics and Rural Sociology has continued its studies on nine projects, eight of which have been approved for development with Purnell funds.

Project No. 1.—An Economic Study of the Peach Industry in Colorado.—This work was initiated in 1926-27 in cooperation with the Division of Farm Management and Costs, Bureau of Agricultural Economics, U. S. Department of Agriculture, and it has been carried during the past 2 years in cooperation with the Extension Service of the Colorado Agricultural College. The original records dealt with labor and material costs in producing peaches. More recently attention has been given to a study of the farm business as a whole.

Farm-business analysis records for the year 1928 were secured during the summer of 1929. The necessary calculations have been made on these records; the information has been transferred to office sheets and the results have been set up in tabulated form. At this stage complete records covering 2 years have been made available. A preliminary report in which comparisons are made for the years 1927 and 1928 is in preparation. Copies of this report will be returned to cooperating farmers during the current year.

Project No. 2.—An Economic Study of Farm Organization and Management in the Greeley Area and in Northeastern Colorado.—This study was begun in 1922 and records have been maintained continuously in this region for a period of 8 years. The project was developed during the early years in cooperation with the Division of Farm Management and Costs, Bureau of Agricultural Economics, U. S. Department of Agriculture. Within the past 4 years the work has been developed entirely by this department.

There are four phases of economic endeavor under consideration at the present time. These include (1) a continuation of detailed farm-accounting records on some 15 or more farms which have been a part of this enterprise since 1922; (2) a detailed study of some representative dairy farms, starting with the calendar year 1929; (3) financial farm records on irrigated farms continuous since 1922; and (4) financial records of representative non-irrigated farms for the years 1927, 1928 and 1929. In addition to the purely statistical material which has been assembled, much valuable information has been secured with reference to farm organization methods, farm practices and farm returns.

A manuscript dealing with the cost of feeding cattle in Northern Colorado has recently been prepared and will be available for publication in the near future.

Project No. 3.—A Study of Costs and Methods of Producing Cattle and Sheep on the Range in Colorado.—Four departments are represented in the study and analysis of this project, and two distinct but closely related regions are involved. The cooperating agencies are: The Bureaus of Animal Industry and Agricultural Economics in the U. S. Department of Agriculture, the Wyoming Experiment Station and this department. Approximately 20 records are being maintained for the North Park area in Colorado and 22 records for the Saratoga Valley in Wyoming.

To date, records have been assembled and checked for 19 ranches. Practically all of the accounts for the year 1929 have been closed and summary statements have been prepared so that cooperating ranchmen may have available financial summaries for the past year. The route man has made an average of six visits per ranch during the past year. A preliminary report relating to the cost of producing hay on North Park ranches is being prepared and will be distributed to cooperating ranchmen early this season.

Project No. 4.—A Study of the Social Status of Spanish-speaking People in Rural Colorado.—Within the past year the collection of material relating to this subject has been completed. A number of meetings dealing with Spanish problems have been attended; a number of conferences in which the leader of the project has participated have been held; a rather extensive list of references has been examined and further observations have been made in the field. The material collected was assembled in the form of a manuscript. This manuscript has been rewritten and worked over in part several times. Within a few days the last chapter dealing with conclusions and suggestions will be completed. This outline will then be submitted for publication.

Project No. 5.—A Study of Taxation in Colorado, Particularly in Its Relation to the Agricultural Industry.—This project has been carried on a cooperative basis with the Division of Finance, Bureau of Agricultural Economics, U. S. Department of Agriculture. During the current year this division has prepared a large amount of statistical information with reference to public-school finance in Colorado.

A beginning has been made in the study of county government. Our local county was selected for the initial work. Colorado Station Bulletin 361, entitled "The Cost of Local Government," has been published and will be distributed shortly. Another manuscript dealing with the cost of public schools in this county has been prepared and is in the hands of the editor. Mr. N. E. Woodard, a graduate student, is making an analysis of the feasibility of establishing a centralized purchasing department for Colorado counties, particularly in con-

nection with securing school supplies. Thus far he has reviewed the literature on the subject published in the United States and Canada and is attempting to secure as much information as possible from several foreign countries.

Project No. 6.—A Study of Methods of Storage and Marketing Practices in Handling Onions on Farms in the Arkansas Valley.—This project was organized in the beginning for the purpose of making a study of marketing practices and storage costs in handling potatoes in the San Luis Valley. The entire enterprise has been developed in cooperation with the Division of Markets, State House, Denver, Colorado.

The results of our investigation, covering a 3-year period in the San Luis Valley, have been completed and the assembled materials are being placed in manuscript form for publication. During the past autumn and the early part of the present year, cost-of-production records have been obtained from some 15 or more farm operators in Otero County. Storage information has also been assembled for these farms and in several cases complete farm-business analysis records have been obtained. It is our intention to prepare and submit a preliminary report dealing with the cost of producing onions and a report likewise on some of the major storage features of this study.

Project No. 7.—An Economic Study of the Apple Industry in Colorado.—In its inception this project was conducted in cooperation with the Division of Farm Management and Costs, Bureau of Agricultural Economics, U. S. Department of Agriculture. During the past 2 years the field work has been developed in cooperation with the Extension Service of the Colorado Agricultural College. The preliminary reports have been prepared and returned to cooperating farmers in this general region. Our work on this project now includes financial studies for 3 years and several types of farming have been considered in this analysis. Material is available for a 3-year preliminary report which will be returned during the summer of 1930.

Project No. 8.—An Economic Study of Land Utilization in Northwestern Colorado.—This enterprise was undertaken in 1927 in cooperation with the Division of Land Economics, U. S. Department of Agriculture, and includes a study of land utilization in Northwest Colorado. Farm-business analysis records have been assembled in Moffat, Routt and Grand counties for 3 successive years. For 2 years preliminary reports have been prepared and returned to cooperating farmers. The Division of Land Economics has given attention to materials collected from the Forest Service, the U. S. Land Office and from county records relative to land utilization in this region.

Project No. 9.—A Study of the Major Types of Cooperative Organizations or Associations in Colorado.—This enterprise was

developed in its early stages in cooperation with the Division of Cooperation, Bureau of Agricultural Economics, U. S. Department of Agriculture. There are now 24 cooperative grain elevators that are furnishing information with reference to such items as number of stockholders and patrons, amount of capital stock, amount and source of working capital, indebtedness, physical properties of each elevator, grading-equipment used, buying and selling policies, cooperative features, etc.

Prior to the development of this study dealing with cooperative elevators, data were obtained from approximately 80 cooperative associations in the state. This manuscript is now in the preliminary stages and will be submitted in bulletin form in the near future. It is our intention, however, to make some further study of these cooperative units before the final outline is published.

Respectfully submitted,

L. A. MOORHOUSE,

Agricultural Economist.

REPORT OF THE ENTOMOLOGIST

To the Director:

Following is a brief report upon the work carried by the Entomology Section of the Experiment Station during the past year:

The only important change in personnel has been the placing of Mr. Louis G. Davis in charge of the work at the Mesa County field station in Grand Junction in place of Mr. Wm. P. Yetter, Jr., who left a year ago to take a position with the U. S. Bureau of Entomology.

Much of the research work in Entomology is carried in cooperation with the funds of the State Entomologist and the Department of Entomology, to the advantage of all three lines of work, as it makes it possible to secure more competent men, and the three phases of the work are very closely related to each other.

The bulletins that have been published from this section during the year are:

No. 352, The Sulphide Sulphur Content as a Basis for Diluting Lime-sulphur for Spraying, by George M. List.

No. 354, Some Factors relating to the Feeding Habits of Grasshoppers, by George S. Langford.

Press Bul. No. 72. Preliminary Notes on the Action of Strychnine on the Wyoming Ground Squirrel (*Citellus elegans elegans*), by W. L. Burnett.

The losses from insect pests during the year have not been unusual as compared with previous years. Among the insects causing heavy losses were: Grasshoppers, cut-worms, and the alfalfa weevil to general farm crops; the codling moth, several species of plant lice and scale insects to the fruit crop; the oyster-shell-scale, elm scale and bark borers to forest and shade trees; and cut-worms, plant lice, the red spider, flea beetles, the onion maggot and the cabbage worms, to garden crops. Experimental work for the purpose of finding better control methods for many of these pests and some others is in progress.

I am giving below a few notes on the projects upon which more or less work has been done during the year, or which have been approved for work during the coming year.

Plant-louse Investigations.—This is an Adams project, carried by Miss M. A. Palmer and the writer. Two technical papers have resulted from the work during the year, giving habits and descriptions of several new species. One of these papers has been published in "Annals" and the other has been accepted for publication and will appear soon. A large amount of work has also been done in the preparation of an illustrated list of Colorado *Aphididae*, Part I of which is about ready for the printer.

Ants in Relation to Plant Lice.—This is a Hatch project in charge of Dr. C. R. Jones. Progress has been made in the gathering of data on life histories and in methods of control. The work will be continued along these lines during the coming year.

Codling-moth Studies.—This project is supported cooperatively on the funds of the State Entomologist and the Experiment Station, the work being chiefly in the nature of comparative tests in the field for the control of the codling-moth in Mesa and Delta counties. In this work we are cooperating with the Bureau of Entomology in the testing of the Siegler treated band for the capture and destruction of the larvae of this insect. The tests to date have given excellent results. The project is in charge of Mr. George M. List, with Mr. J. H. Newton and Mr. L. G. Davis as helpers.

Codling-moth Control by an Egg Parasite.—This is a Purnell project which is carried in cooperation with the State Entomologist's funds, and is in charge of Mr. List. Many difficulties have arisen in the work of breeding this parasite, to overcome which has called for much ingenuity and perseverance in devising apparatus and methods of securing proper temperature and humidity to insure success. At present about 30,000 parasitized eggs are being shipped daily to be used in the orchards of the State to determine what effect may be secured by this parasite in the reduction of wormy apples and pears.

Grasshopper Control.—The work in this project has been in cooperation with the Bureau of Entomology and in charge of Mr. Frank

C. Cowan, and has been directed chiefly to the control of the Mormon Cricket in Northwestern Colorado. Very gratifying results have been secured, and it now seems probable that, by the end of the coming summer, this insect will be eliminated as a serious pest to the settlers in Moffat, Routt and Rio Blanco counties of this state, for several years to come.

Potato Flea Beetle.—This project, which is being supported wholly on state funds, has been in charge of Mr. L. B. Daniels who has been able to add materially to our knowledge of the life habits of this insect and its methods of control during the past year. The investigation will continue during the coming season.

Resistance of Bees to Foulbrood.—Mr. R. G. Richmond, who has been in charge of this project, considers it practically completed except for the assembling of his data and the publication of results.

Colorado Insect Fauna.—This project is in charge of Mr. Sam McCampbell, who has made good progress in accumulating additional data on Colorado insect fauna and related host plants.

Relation of the Honey Bee to Clover-Seed Production.—This project, in charge of Mr. R. G. Richmond, is supported cooperatively by Experiment Station and State Entomologist funds. It was started last summer, and already much important information has been secured. It seems probable that Mr. Richmond will be able to complete this investigation during the present summer.

Range Insects.—This is a new project to be supported on state funds. It has been placed in the hands of Mr. L. B. Daniels, and is for the purpose of determining the extent of insect injury to the more important native range areas in the state and the practicability of economic control.

General Insect Investigations.—This project is kept alive from year to year to enable the Entomology Section to meet any emergency that may arise unexpectedly for the control of an insect pest not included in the regular program. But little work was called for on this project the past year.

Rodent Life Histories.—This project is in charge of Mr. W. L. Burnett and has for its purpose the securing of additional data that may help in devising methods of control for injurious rodents. Fair progress has been made in this work during the year.

Rodent Poisoning.—Control of our most destructive rodents in Colorado is accomplished largely thru the use of food poisons. Mr. W. L. Burnett, who is in charge of this project, has obtained some very significant results in his experiments, especially in the use of "Colorado Formula 46," which were published in Press Bulletin 72 from the station.

The most important results were that prairie dogs and Wyoming ground squirrels, at least, are not repelled in the least by strychnine or other ingredients used in this formula, and that they eat the poisoned grain more freely than they do the unpoisoned when the two are placed side by side, even to the point of taking a fatal dose. This was true even when the poisoned grain was taken in less than fatal doses for many days before the lethal dosage was reached.

Respectfully submitted,
C. P. GILLETTE, Entomologist,

REPORT OF THE HOME ECONOMIST

To the Director:

The project underway during this year is one on the Baking of Flour Mixtures at High Altitudes.

The manuscript reporting on the technical work of the project is now in the hands of the printer.

During this fiscal year, the major part of the time has been spent in the preparation for the second phase of the project; the interpretation, from a physical chemistry standpoint, of technical results reported in the manuscript.

In preparation for this interpretative work, it was necessary to secure better control of all variables. The insulation of the laboratory, more accurate control of oven temperature, more uniform distribution of heat within the oven, and humidity control—these are some of the problems that have required much thought and time.

Early in April, Miss Florence Schott, leader in research, and Miss Margaret Scheve, were accorded laboratory privileges at the University of Minnesota. There they have access to scientific apparatus we are scarcely justified in purchasing.

Their studies include surface film, surface tension and foam behavior of constituents and combinations of constituents of cake mixtures.

Respectfully submitted,
INGA M. K. ALLISON, Home Economist.

REPORT OF THE HORTICULTURIST

To the Director:

I submit herewith a brief report on the work on the different horticultural projects. The report will necessarily be short since not much has been done on the project since the last report. However, a brief statement on each project will give you an idea of what is being done.

Spanish-Onion Breeding.—This work is carried on both at Fort Collins and at Rocky Ford. A number of crosses between the Valencia and the Brown Australian onions were made last year and the seed has been sown this spring from which selections will be made at the end of the season. Also, for 2 years we have been doing selection work with the Valencia onion, using a definite type, both as to shape and to color. Several thousand selected bulbs have already been planted and are doing well. The season has been very favorable for the seeding and for the setting out of the bulbs and we anticipate fine results during the season.

Development of Tipburn-resistant Varieties of Head Lettuce.—This work is carried on at Fort Collins. A number of crosses have been made between the variety known as New York, the common type of head lettuce, and the small-headed purple-leaved variety known as Mignonette. The results of these crosses, from the last 2 years' work, have given us a supply of seed that was planted this spring and the plants are now growing in the garden. There will be considerable work during the season in the way of selection and roguing out of undesirable types and the fixing of those crosses or hybrids that have proved acceptable. It is hoped that we shall be able to produce a variety or varieties that are tipburn resistant. It is a well-known fact that a variety like the Mignonette is highly resistant to this disease. This work is progressing very satisfactorily.

Potato-variety Testing and Improvement by Selection.—This project has been in progress for a number of years and will be continued. The work is done at Avon where conditions are favorable for this type of work. There is a wide variation in varieties and also in strains of each variety. We hope by careful study of the varieties collected and grown, as well as the strains, to bring out superior yielding varieties and varieties that are more resistant to disease.

Strawberry Investigation.—The work of this project has been in progress for the last 3 years. We have been having considerable difficulties with most of the varieties under observation for the reason of root yellows, a disease that is becoming very prevalent in Northern Colorado and is spreading to other sections. Some varieties seem to be more resistant than others. We are mainly concerned in selecting individuals that appear to be resistant, to propagate these for increase and to test them out in larger areas.

General Variety Testing of Tree Fruits.—This project is carried on at Austin in Delta County, Colorado. It is of long duration and the reason for its inception was the constant addition or additions of new varieties to our fruit list. Some of these individuals have commercial possibilities and in order to test them out and be in position to advise the growers, we have provided for space so that all new varieties can be

tested out and fruited and the desired information obtained. This work has been going on now for the last 6 years and some really promising varieties of fruit in the way of new varieties have been brought out. This work will be indefinitely extended and publications will be forthcoming when we have a sufficient number of kinds to report.

Grape Growing.—The grape-growing project on the Western Slope, especially with reference to European varieties, has also been in progress for 4 or 5 years. We have demonstrated that European grapes can be grown successfully in Western Colorado, provided proper care is given the vines and also proper protection during the winter. If these precautions are taken, most of the standard varieties of European grapes can be grown with profit. We should be in position to give definite information within a year or so.

Orchard Management.—The project of general orchard management, including cover crops, etc., has been carried on at Austin in connection with the work of the State Horticulturist. The results of this work have been very encouraging. The increase in production and increase in quality under a system of orchard management has been very noticeable. The fruit growers of Delta County are watching the work and are gradually adopting the method we are using. We expect to publish a bulletin on this work during the year.

Raspberry Investigations.—This project started 2 years ago, using varieties that we had in the garden and also by adding new varieties. There has been considerable controversy as to the present methods of pruning and thinning the canes of raspberries. The results, as tabulated during the winter months, show conclusively that pruning should not be excessive; that the number of canes to the hill should be reduced and possibly, instead of setting the plants in hills, they should be spaced individually in the row, giving a better chance for lateral growth of the canes. From the data obtained, we believe that a better system of handling raspberry plantations should be worked out and with better results to the growers. Preparation has been made to check on last year's work and to get a larger amount of data on which to base final conclusions.

This covers the main projects as outlined.

In addition, we have the variety testing and selection of garden peas, a project that we have been carrying for the past 3 or 4 years and we hope to reduce the number of varieties under observation and to increase the stock and make further selections. This work has been of considerable value in developing more productive and disease-resistant strains of peas, particularly varieties like the Dwarf Telephone.

Respectfully submitted,

E. P. SANDSTEN, Horticulturist.

REPORT OF THE IRRIGATION ENGINEER

To the Director:

During the year ending June 30, 1930, the following projects have been actively pursued:

Measurement of Water.—Since the development of the smaller sizes of the improved Venturi flume in the hydraulic laboratory, considerable interest in the use of larger flumes has been manifested. The performance of the 40-foot improved Venturi flume on the Fort Lyon Canal has been such as to fully verify the accuracy and constancy of this device in measuring large flows under adverse conditions of sand and silt carried in the streams.

Because of the practicability of the several large flumes in operation in the Arkansas Valley last year, others have since been constructed, mostly of reinforced concrete, while in the valley several other canals are to be equipped with this type of measuring device very shortly.

For previous large installations an automatic discharge indicating mechanism was provided, consisting of a graduated metel ribbon tape actuated by means of a float. To completely indicate the discharge thru the improved Venturi flume, two depths or heads, H_a and H_b, are required, and recently an instrument has been developed which records these two heads on a graduated chart by means of two pens, using different-colored inks; also incorporated in this instrument is a simple means of indicating the values of the heads, H_a and H_b in feet, as well as showing the rate of discharge in second-feet. The indicated rate of discharge is only true for condition of submergence not exceeding about 80 percent. Twelve such instruments are being built at the hydraulic laboratory and are being installed on a number of the large flumes now in commission in the Arkansas Valley.

The requirements of measuring flowing water have necessitated the design and calibration of a 3-inch improved Venturi flume. The 40-foot flume has a maximum capacity of more than 2,000 second-feet, while the small 3-inch size will accurately measure about 0.02 second-foot as a minimum. This great variation in range of discharge permits meeting practically all requirements from an irrigation standpoint.

The adjustable tube meter, which has been developed at the hydraulic laboratory, is to be installed in the Arkansas Valley on a small channel of flat grade having bad sand and silt conditions. Laboratory tests indicate that this device is well suited for the measurement of flowing water where little loss of head is available, and also where deposits in the channel are contending factors.

An extensive accumulation of current-meter data has been computed and compiled with the intention of preparing a report suitable for publication as a bulletin.

This project is supported by Hatch and State funds.

Pumping Projects.—The study of the relative costs of irrigation by pumping and that supplied as ditch or reservoir water made in Weld County during the summer of 1929, shows that under the more favorable conditions for pumping the cost per acre-foot of water delivered is practically on a par with the cost per acre-foot delivered by the ditch. A similar study is under way for the summer of 1930 in the Arkansas Valley near Fowler. It is not expected that the costs of water by pumping and that delivered by ditch for the present set-up will be as close in agreement as those found in Weld County last year.

Maps of various sections of the state have been prepared on a suitable scale, showing the location of existing wells used for irrigation supplies. Each well is numbered, and by reference to a filing card all pertinent information may be had as to any particular well, such as depth, diameter, probable yield, cost, and, where available, the log of material encountered.

Observations are being made on the possibilities of drainage by means of pumping on two farms near Eaton.

Evaporation from a Free Water Surface.—This project has been virtually closed. The excellent report by Carl Rohwer covering this extensive study has been completed and submitted for publication. This project was carried out cooperatively with government funds and the report is now being considered as a bulletin to be issued by the United States Department of Agriculture. In connection with this project, some special observations are being carried on the evapo-transpiration losses from blue grass and swamp grass grown in tanks with the water-table at 6, 12 and 18 inches. Fallow tanks are being maintained in each of these series and also two tanks having a free water surface. Meteorological data are observed in connection with this study.

Meteorology.—This project has been a continuing one for many years and is supported wholly on state funds. The meteorological data, observed each day at 7 a.m. and 7 p.m., constitute a very popular source of information. Unusual weather conditions bring many inquiries as to maximum and minimum temperatures, as well as intensities of storms. Daily temperature and precipitations are published in the local paper.

Project Work for the Coming Year.—It is expected that the present installation of large improved Venturi flumes in the Arkansas Valley and elsewhere in Colorado will provide facilities for the complete study of this subject. Observations on canals in the Arkansas Valley and other places in Colorado indicate the seriousness of the effect of sand and silt deposits from the standpoint of operation. Numerous methods are now employed in combating this menace which, in many cases, appear to be ineffective. The satisfactory solution of this problem is most urgent and it is especially recommended that attention be given to the study of this important matter.

To more ably recommend the proper location, depth and size of wells for irrigation supplies, some attention is now being given to the possibility of investigating the problem. In general, it is proposed to sink several wells of various depths and diameter, in a selected area, and then study the effect on yield and draw-down, as well as perforation of casing. From these data it is expected that more assurance can be placed on suggesting to the farmer the proper requirements of well and equipment in producing an efficient water supply.

Respectfully submitted,
RALPH L. PARSHALL, Irrigation Engineer.

REPORT OF THE VETERINARY PATHOLOGIST

To the Director:

Following is a brief report by projects of the work being carried by the Veterinary Pathology Section:

Sheep Losses in the Feedlots.—The unusual prevalence of coccidial dysentery has given us an opportunity to write up nine successive outbreaks, and submit this material for publication.

We have accumulated a considerable number of cultures from cases of pneumonia, which are waiting time for their determination.

The paper detailing the work on thallium poisoning in sheep will be published in the Journal of the American Veterinary Medical Association for June.

Death Losses in Lambs on Heavy Grain Feed.—We have carried 10 lambs in an attempt to reproduce the condition of over-eating, making weekly observations on the sugar content of both the blood and urine, but so far we have not succeeded in reproducing the typical condition.

Contagious Abortion.—A recent test on the college herd shows that it is still clean. After the re-infection of the range-management herd, it now seems to have been freed of all re-actors.

The herd at Fort Lyon still continues to give us trouble, but we have finally found an explanation of the reason for the perplexing conditions that have prevailed there during the last 3 years. Two animals in that time have aborted that have been negative at the end of the 30-day observation period, and have been returned to the clean herd, only to become positive at some later time. This seems to indicate that returning aborting animals to the clean herd, even tho they are negative, is a dangerous practice. Our experience in the college herd, where five negatively re-acting aborters were found, indicated that this was a safe procedure. Another problem that has been fraught with disaster in the Fort Lyon herd is the aborting of animals previously clean, and then becoming re-actors at the next test.

General.—There is an increasing demand for service work in the production of abortion-free herds in the state.

Because of the interest in undulant fever in man, we have, up to date, run blood tests on 30 patients, which have resulted in the finding of seven positive cases. All of these have been mature, the youngest being 19 years of age. Two out of the seven have been veterinarians. There has been one death.

Among poultry diseases, infectious bronchitis in baby chicks and leukemia in mature fowls ought to be mentioned as of unusual prevalence.

Tabulation of our diagnostic work done in the laboratory follows:

Avian	145	Feline	3
Bovine	33	Ovine	46
Canine	12	Swine	7
Equine	4	Rodents	5
Miscellaneous	51	Human	117
Milk for abortion test 2	2 Pos.	Water	2

Baby chicks examined for White Diarrhoea—131 lots, 79 positive

Examination for rabies 20 7 positive

Blood Tests

Contagious abortion	2,176	453 positive	20.81 percent positive
White Diarrhoea	4,592	342 positive	7.44 percent positive
Undulant Fever in man	15	5 positive	33.3 percent positive

Publications

"Coccidiosis in Cattle," by I. E. Newsom. Veterinary Medicine, Vol. XXIV, No. 10, October, 1929, pp. 429-431.

"Pathogenic Spore-Bearing Anaerobes in the Carcasses of Sheep," by I. E. Newsom, Floyd Cross and Herta S. Dobbins. Jr. of Inf. Dis., Vol. 45, No. 5, November, 1929, pp. 386-392.

"Sheep Diseases," by I. E. Newsom. Vet. Med., Vol. XXIV, No. 12, December, 1929, pp. 526-532.

"Paratyphoid Dysentery in Lambs Again," by I. E. Newsom and Floyd Cross. Jr. of the A. V. M. A., Vol. LXXVI, N. S. Vol. 29, No. 1, pp. 91-92.

Respectfully submitted,

I. E. NEWSOM, Veterinary Pathologist

ENGINEERING DIVISION

To the Director:

I am submitting herewith the reports from the Engineering Division of the experiment Station for the year ending June 1, 1930.

Very truly yours,
L D CRAIN, Vice Director

REPORT OF THE CIVIL ENGINEER

To the Vice Director:

Following is the annual report of the Civil Engineering Section of the Experiment Station and covers the work done by this section from June 1, 1929 to June 1, 1930.

Usually the heavy work in the Road Materials Laboratory comes during the summer time when much material is sent in by the State Highway Department to be tested. The summer of 1929 was no exception and the usual amount of testing work on road materials was done. Late in the fall, however, about 400 soil samples were sent in, together with a lot of oil samples, and this kept the force extremely busy all winter and spring of 1930.

This work is completed at this writing and we are ready for the concrete cylinders and aggregates which are now coming in and will continue to come in thruout the summer.

During the past year 1,737 concrete cylinders representing all bridges, pavement and culverts constructed by the state have been tested. It is interesting to note that a careful control of field mixes based on the results of tests made in this laboratory has increased the average strength of Colorado concrete pavements from 3098 pounds per square inch in 1926 to 3618 pounds per square inch in 1927, and 4023 pounds per square inch in 1928. These figures were compiled by Mr. Roy Randall, Office Engineer of the State Highway Department. This increase in strength of concrete in our highway pavements means lower maintenance costs and better wearing road surfaces for Colorado in years to come. The above cooperative work with the State Highway Department constitutes the bulk of the work done in the roads laboratory. There are, however, several experimental projects upon which data are being gathered.

No. 1. The Frost Heaving Project has been carried forward thruout the year. The changes in elevation of points on two concrete slabs are being recorded and periodic tests of moisture content of the subsoil taken. This work was started in December, 1928, and has now been carried thru two winters and one summer. We should be able to draw some tentative conclusions from this data by next spring.

No. 2. Pavement Cores and Subgrade.—During the summer of 1929 the State Highway Department continued to take core samples from Colorado concrete pavements and corresponding samples of subgrade on the Denver-Colorado Springs Highway. Two hundred and twelve cores and 423 samples of subgrade soil were sent in during the fall and were tested during the winter period. It is intended to write a summary of the results of these tests and the conclusions drawn, early next winter.

No. 3 Light Asphaltic Road Surfaces.—This is a new project which gives much promise of good results. It is intended to carry out, under field conditions, the construction of several miles of oiled graveled road and then watch the wearing qualities of this road, sections of which are to be treated with different oils. This summer six, half-mile sections of this kind of road will be constructed between Eaton and Nunn, Colorado. Each section to have the same subgrade and aggregate, the only variable being the oil to be used. From the wearing qualities of these sections will be picked two or three of the best oils. These selected oils will be used the following summer on another experimental road and the type of aggregate will be varied on the different sections. In this way we hope to find the best oils and the proper aggregate to use on oiled graveled roads for different sections of the state.

No. 4. Road Materials of Colorado.—Work on this project during the year has consisted of testing samples of surfacing materials and a smaller number of samples of concrete aggregate sent to the laboratory by resident engineers of the Highway Department.

No. 5. Road Oils.—Oiled gravel surfaces for all secondary roads in Colorado seem to solve the problem if properly constructed and maintained. This type of road has been very successful in several of our Western States. At the end of the summer of 1930 Colorado will have approximately 200 miles of this kind of road. During the past year 218 oil samples were tested in the laboratory as it is found that certain qualities of the oil are essential to successful wearing qualities of this type of highway.

A number of samples of Asphalt wearing surfaces for bridges have also been tested in the laboratory during the past year.

Taking it all together the year has been a busy one. We were unfortunate in having to change testing engineers during the year. Mr. Don Tripp resigned on September 1 to take a position with the Missouri State Highway Department and Mr. Carl Carpenter took up the work on October 1, 1929. A change of this kind always disrupts the work to a greater or less extent. Mr. Carpenter, however, has shown himself to be a capable man and after becoming acquainted with the nature of the work, has carried it on in a satisfactory manner.

The work has been done by himself and three student assistants,

altho it was necessary to put on an extra full-time man for about 6 weeks during the heavy testing period.

There is a good deal of drudgery connected with this work for it consists in making the same tests over and over again on different samples.

Altho the work piled up on us last fall and early winter, it is now all cleaned up and we are taking care of the tests as the samples come in, without delay.

Respectfully submitted,

E. B. HOUSE, Civil Engineer

REPORT OF THE MECHANICAL ENGINEER

To the Vice Director:

Following is the annual report from the Mechanical Engineering section of the Experiment Station for the year ending June 1, 1930.

The Mechanical Engineering Section has done no work during the past year due to the fact that Mr. Logan, who was the assistant in charge of the work, resigned to take a position at the Kansas State Agricultural College, and that a suitable successor has not been selected up to the present time.

The coming year we hope to do considerable work in the section as a man has been selected and if he is approved by the board, will be in charge of the work.

Respectfully submitted,

L D CRAIN, Mechanical Engineer

REPORT OF THE EDITOR

To the Director:

Less than the pro-rata number of bulletins were printed during the 7-month period, December 1, 1929, to July 1, 1930, probably because the main rush of publications usually comes at the close of the summer vacation. There were, however, 332 bulletin pages with a total edition of 26,000.

Approximately one-fourth of the news and information stories sent out from this office were about experiment station workers and activities. In addition to the newspapers of Colorado, we are now sending the "blue sheet" to about 185 farm and home magazines thruout this country and Canada. Inquiries from without the state, and especially returns from our clipping service, prove that this out-of-state circulation is decidedly worth while.

The editor had charge of the experiment station exhibit at the National Western Stock Show in Denver during January. Considerable new decorating had to be done.

Following are the publications issued during the 7 months:

Bul. 354—Some Factors Relating to the Feeding Habits of Grasshoppers. 53 pages. 1,500 copies.

Bul. 357—The Home Vegetable Garden.
45 pages. 5,000 copies.

Bul. 359—Ideal Types for Colorado Standard Potato Varieties.
23 pages. 5,000 copies.

Bul. 360—Pastures for Spring and Fall Grazing in Mountains of Colorado. 12 pages. 2,000 copies.

Bul. 361—The Cost of Local Government in Larimer County, Colorado. 84 pages. 4,000 copies.

Bul. 308 (Revision)—Adobe Brick for Farm Buildings.
30 pages. 3,000 copies.

Press Bul. 71—Corn and Hog Millet for Fattening Lambs.
6 pages. 2,500 copies.

Press Bul. 72—Action of Strychnine on Wyoming Ground Squirrels.
4 pages. 1,500 copies.

Forty-second Annual Report. 75 pages. 1,500 copies.

Respectfully submitted,

I. G. KINGHORN, Editor

REPORT OF THE VETERINARIAN

To the Director:

In the Veterinary Section there is but one project, that of Animal Diseases. This is a general project supported by state funds, and it contemplates incidental investigation of animal-disease outbreaks, and the cooperation with state and national authorities in their control.

Progress in the knowledge of diseases which afflict the domesticated animals is possible only by eternal vigilance and painstaking investigation. New disease conditions are constantly arising and must be met by adequate prophylactic and therapeutic measures.

In a general way livestock conditions in Colorado, from the standpoint of health, are normal at the present time. Just now the abortion disease of cattle is in the limelight. It has been stated, and is generally accepted, that contagious abortion in cattle is causing as much or even greater financial loss than tuberculosis. The progress made in the last 12 years in the control of tuberculosis marks an outstanding achievement in this line of endeavor.

Malignant Catarrhal Fever, which was troublesome during the early winter months has subsided. At the present time the diseases of animals that are of most economic importance may be summarized as follows: Contagious abortion in cattle; coccidiosis in several species of farm animals; paratyphoid conditions, especially of hogs; hog cholera; anemia of pigs; preparturient paralysis of ewes; chronic progressive pneumonia of sheep; white diarrhoea of chicks; blackhead disease of turkeys; lamb losses in the feed lots; poisonous plants.

Respectfully submitted,

GEORGE H. GLOVER, Veterinarian

Bulletin 344 February, 1929

THE PRINCIPLES OF BREAD-MAKING

By N. E. Goldthwaite

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*On leave, 1928-29.
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THE PRINCIPLES OF BREAD-MAKING

By N. E. Goldthwaite*

PART I. ANTIQUITY OF BREAD-MAKING

Interest in any present-day knowledge or art is increased if we can trace its development from its beginnings, and so form mind-pictures of its evolution. To do this with an art so ancient as bread-making is not possible, yet here and there in the record of man's past we glimpse a little of its early history. That bread-making had its beginnings long ages preceding man's written history, both geology and archeology combine to prove. Apparently, those beginnings consisted merely of wetting or soaking coarsely ground grain or nuts, and finally baking the product on hot stones before a fire. When, however, bread-making is finally mentioned in written history, the mention is so casual, that we can only conclude that it had long been a human practice—so long that it was simply taken for granted.

> "Bread-making, or at any rate, the preparation of cakes from flour or parched grain by means of heat, is one of the most ancient of human arts."[1]

We get some idea of its antiquity when the geologist tells us that in some of the prehistoric Swiss lake-dwellings

> "have been found the calcined remains of cakes made from coarsely ground grain . . . . . that date back to the Stone Age. These cakes were made of different kinds of grain, barley and one-grained wheat being among the ingredients. This bread was made, not from fine meal, but from grain crushed between some hard surfaces. In these lake-dwellings have been found many round-shaped stones which were evidently used for pounding or crushing grain against the surface more or less concave of another stone."[2]

Then the archeologist, from his researches, tells us that excavations of ruins in ancient Chaldea, expose in every courtyard an oven for bread-making, while close by are found the grinding-stones that were evidently used. Also, he tells us that remains of cakes of grain have been found in ancient Egyptian tombs—tombs which date back to 3000-4000 B. C. That these ovens of Chaldea and the grain cakes of Egypt must have come into being long ages succeeding the Swiss lake-dwellings of the Stone Age, is probably true.

The Bible, in Genesis XVIII, records that Abraham stays his three visitors in order to rest them and to refresh them with bread, and that forthwith he says unto Sarah his wife,

> "Make ready quickly three measures of fine meal, knead it and make cakes upon the hearth."

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*Dr. N. E. Goldthwaite formerly carried on home economics investigations for the Colorado Experiment Station but resigned in 1927 on account of her health.

[1]Encyclopedia Brittanica, Edition XI, Article on Bread.

[2]Encyclopedia Brittanica, Edition XI, Bread.

The date ascribed to this event is about 1900 B. C.

Further, in Exodus XII, 8, 15, 39, a distinction is made between unleavened and leavened breads, showing that at this time (about 1500 B. C.), the difference between the two kinds of bread was well known. This distinction is also made in Exodus XIII, 6-7; XXIII, 15; XXXIV, 18, 25; Numbers IX, 11; XXVIII, 17; Deuteronomy XVI, 3, 8.

To leaven means "to excite fermentation in; to raise and make light, as dough;"[3] to raise dough by means of incorporated gas or air. Raised bread or "light" bread is leavened bread; it has been raised by means of the gas, carbon dioxide, evolved by yeast. How yeast does this will be considered further on. The unleavened bread of the Hebrew Passover was, and is, bread made by mixing flour and water, adding a bit of salt, rolling the dough out thin and baking. Such unleavened bread was evidently a lineal descendant of the "cakes" made from coarsely ground grains found in the Swiss lake-dwellings of the Stone Age.

It is a far cry from such coarsely ground unbolted grain and the cakes therefrom, to the finely ground bolted wheat flour and the "light" breads therefrom of today. When humanity first learned to try to "raise" or leaven bread, is entirely unknown. It has been conjectured[4] that sometime some of the wet mass of coarsely ground grain prepared for cakes was accidentally left over, and later, when baked, was found to yield a cake of a different or lighter texture than the earlier baked dough. This lighter texture was due, of course, to the action of the wild yeast that had fallen from the air into the left-over dough, and had had time to grow there. But it took long ages to discover this—not till the scientist, with his microscope and his exact methods, appeared and put his exact questions to Nature, and thereby discovered yeast cells and their behavior while growing. Further, it has been conjectured that sometimes such left-over dough was mixed with freshly prepared dough, and that the product, when baked, was found to be a lighter, more-palatable cake than when made from a freshly prepared dough alone. By repetitions of this process, humanity was on the way to learn to make leavened or yeast bread.

Probably these conjectures are not far from the truth, and they do help us to form mind-pictures of what occurred in those far-off days.

One wonders, when one visits the interesting Mesa Verde region of southwestern Colorado, and there sees within the ruins of those long-deserted cliff dwellings, the very stones formerly used

[3]Century Dictionary.

[4]Encyclopedia Brittanica, Edition XI, Bread; Richards, Chemistry of Cooking and Cleaning.

for grinding grains, what sort of bread, if any, the users thereof produced. Did they eat the ground grain direct?—or did they produce a "cake" made by mixing coarsely ground cornmeal with water and baking it on a flat stone? One still finds occasionally in those long-deserted dry rooms, ears of corn, evidently raised on the mesas above. If so, the product must have been closely akin to the hoe-cake that is yet made in the south; closely akin also in manner of making, at least, if not in grain used, to the cakes of the Swiss lake-dwellings; possibly to those of the ancient Egyptian tombs; and possibly to the cakes which Sarah served to Abraham's three visitors.

PART II. STUDY OF BREAD INGREDIENTS

The Century dictionary defines the term bread as "a kind of food made of the flour or meal of some species of grain by kneading it (with the addition of a little salt, and sometimes sugar) into a dough, yeast being commonly added to cause fermentation or 'lightness,' and then baking it." That is the kind of bread considered in this bulletin—yeast bread, or "light" bread as it is sometimes called. Obviously, the basis of such bread is the flour or meal used, and usually this is wheat flour.

Three fundamental ingredients, water, flour, and yeast, are essential in making yeast breads; the other three ingredients commonly employed—salt, sugar and fat—are non-essential to the main problem of bread-making. To understand the underlying principles of making yeast bread, it is of prime importance to become thoroly acquainted with wheat flour and yeast.

STUDY OF WHEAT FLOUR

Every housewife knows that if wheat flour is stirred up with as little water as it will conveniently take up, a tenacious and more or less sticky dough that can be kneaded is obtained. It is to this unrivalled power of forming a tenacious dough, when wet, that wheat flour owes to its superior bread-making qualities. Rye flour or meal is second to wheat in this dough-making quality. Other flours or meals make doughs to a very limited extent, or not at all, as cornmeal.

THE STARCH AND THE GLUTEN OF WHEAT. To understand this important dough-making quality of wheat flour, we need to give it a little first-hand study. For this purpose let us wash the starch[5] out of a small portion of flour and then examine the sticky sub-

[5]In Colorado Agricultural Experiment Station Bulletin 297, Potatoes from the Housekeeper's Standpoint, Part III, the present author discusses the relationship of the human body to the earth. In this discussion, such terms as elements, compounds, molecules, carbohydrates, starch, protein, dextrin, carbon dioxide, etc., are explained very simply. Those who are interested will find The Principles of Bread-making more easily understood and more interesting, if they will study simultaneously Part III of the aforesaid bulletin.

stance left. Hence, into a half cup of wheat flour, stir very gradually just enough water to form a stiff dough; cover over with a damp cloth and let it stand about an hour. Then transfer this dough to a small square of clean white muslin, and with a string tie the corners and edges of the cloth together to form a loose covering. Now fill a large bowl, or a pan, three-fourths full of cold water, immerse the dough-ball within, and work it gently but thoroly till starch ceases to appear thru the meshes of the cloth; thruout this process be very careful not to allow the sticky substance that appears, to ooze thru; keep that within the cloth. Finally, rinse the dough-ball carefully—under running water if convenient. Notice how milky-looking the water in the bowl has become; this is due to the starch washed out of the flour. Let the bowl with its contents stand till its contents have settled thoroly; this will take some hours; later, we will examine it.

Meanwhile, open the muslin covering of the dough-ball and examine the sticky substance left therein. Compare its color with that of the flour used. With hands thoroly wetted (soaked, even), pull some of this substance off the ball and notice its strength, its toughness, its elasticity. This sticky substance is the gluten of wheat; gluten is the dough-making substance—the substance that differentiates the flour of wheat from that of all other grains—the substance that makes a kneadable dough possible from wheat flour.

Gluten is protein material, and it consists of several proteins, the principal ones of which the chemist has named *glutenin* and *gliadin*, because of their glue-like qualities. The term gluten itself is simply the Latin word *gluten* meaning glue, and from it the word glutenin is derived; the word gliadin is derived from the Greek word *glia*, also meaning glue. Upon the proportions and tenacity[6] of these two proteins depends principally the so-called strength of flours to which we shall give more attention further on.

Now, carefully remove the sticky gluten from its muslin covering; coax it into a little cake and bake it in a rather hot oven. Notice how, on baking, it puffs out and becomes several times its original size. Break it open and notice its texture. Does not this texture suggest to you the fact that probably it is gluten that forms the framework of a loaf of bread?—that gluten is the substance that imprisons the gas produced by yeast and so makes possible the raising of bread? This point also we shall return to further on.

To digress for a moment: Perhaps when you were a child you really made the acquaintance, and a very pleasant one, with gluten—only you did not know it by that name. Perhaps then you delighted, like many another child, to get possession of a nice clean

[6]Osborne, American Chemical Journal, Vol. 15, pp. 468-471; Snyder, Studies of Bread and Bread Making, U. S. Dept. of Agriculture, Bulletin 101, p. 57.

handful of wheat to chew "to make gum of!" No gum you could possibly buy was so satisfactory as the "wheat gum" you could make on the spot! You well remember how you used to chew your handful of wheat very cautiously at first, lest you inadvertently swallow the precious stuff, and how by such cautious chewing you soon had a nice "cud of gum" left in your mouth that you could properly enjoy. Of course, what you had really done, in this careful chewing process, was to disengage the starch from the gluten, and to swallow the starch more or less unconsciously, while you carefully reserved the gluten in your mouth. The precious gluten was your "gum."

Now let us return to the bowl with its milky-looking liquid which has been standing for some hours to settle. If thoroly settled, pour off the clear water and let the remaining starch dry. When it is thoroly dry, break it up and transfer it to a measuring cup. How does the amount of starch you have obtained appear to compare with the amount of flour originally used? Of course this comparison will be more satisfactory if you first powder the dry starch. Notice that your starch is the amount you have washed out of one-half cup of flour—roughly one-eighth of a pound. If you have access to a good microscope you will be interested to compare the markings on wheat starch with those on potato starch.[7]

RESULTS OF SOME STARCH AND GLUTEN EXPERIMENTS.—Figure 1 shows the amounts of starch washed out of two different brands

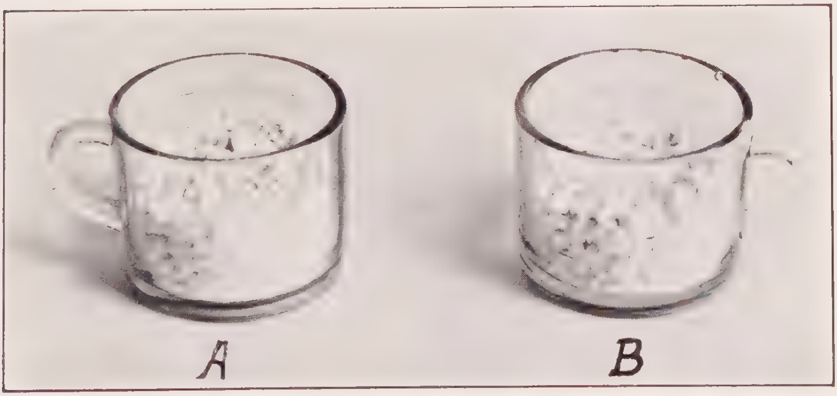

Figure 1.—Showing amounts of starch washed out of one-fourth pound each of two different flours.

of flour, A and B. Identical weights of these flours one-fourth pound—were taken in each case and nearly identical weights of

[7]Goldthwaite, Potatoes from the Housekeeper's Standpoint, pp. 8-9, Colorado Agricultural Experiment Station Bulletin.

starch were obtained; about 70 percent by weight of each flour appeared by this roughly quantitative method, to be starch.

Figure 2 shows the wet gluten cakes remaining after the washing out of the starches shown in Figure 1. On stretching while wet, gluten A showed a greater toughness and elasticity than gluten B.

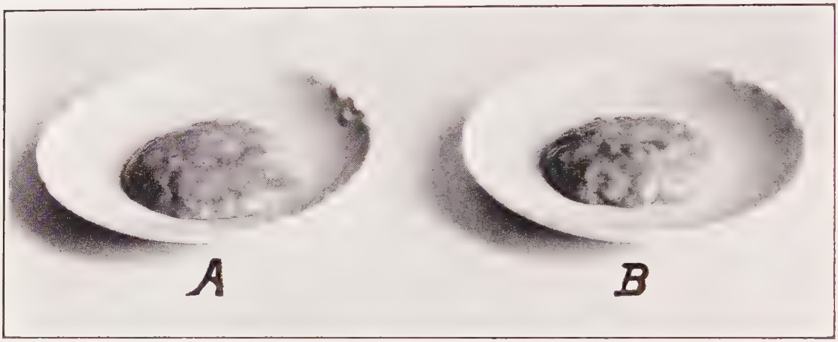

Figure 2.—Showing wet gluten cakes remaining after removal of the starches shown in Figure 1.

Figure 3 shows the same gluten cakes after baking. Notice the difference in size. Gluten A, which when wet was stronger and tougher than gluten B, has baked the larger cake. This difference in size is due to the quality of the gluten rather than to the quantity, which was nearly the same for equal weights of the two different flours.

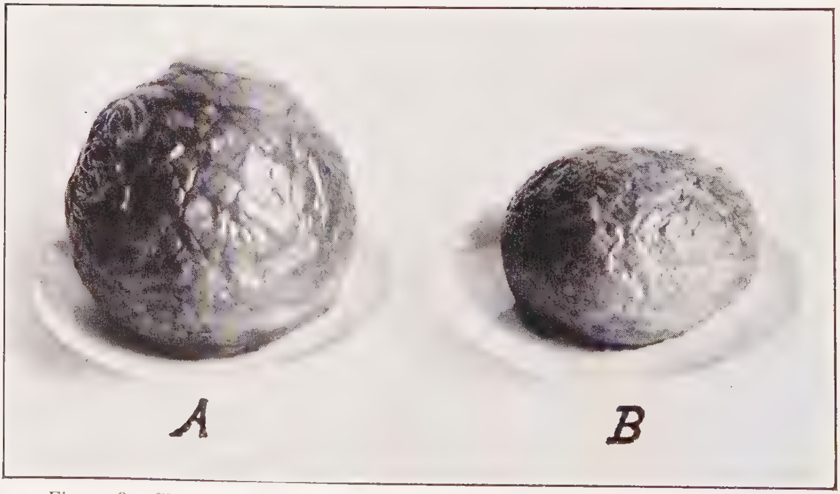

Figure 3.—Showing the results of baking the two wet gluten cakes shown in Figure 2.

STRONG FLOURS AND WEAK FLOURS.—Because of its tough, elastic gluten, flour A is supposed to be an especially good bread flour —it is a strong flour; however, flour B with its less tough, less elastic gluten—and hence a rather weak flour also produces excellent bread when properly handled.

Wheat sown in the spring and harvested the same season is known as spring wheat; while wheat sown in the fall and harvested the following season is known as winter wheat. The gluten from spring wheat is usually strong and elastic, while that from winter wheat is less strong and less elastic. Hence, spring-wheat flour is usually a strong flour, and is generally considered a good bread flour; while the flour from winter wheat is usually weak, and is considered better fitted for pastries than for bread. However, scientific investigation has shown that the gluten contents of these spring and winter wheats often grade into each other, depending upon the weather conditions when the wheats were growing, and also upon the strain of wheat grown. The great milling companies keep chemists constantly at work in their efforts to so blend their wheats that any given brand of flour will be constant in its strength.

Experienced cooks can tell much concerning the strength or weakness of a wheat flour by its feel and color. A strong flour has a somewhat granular feel, and when grasped firmly in the dry hand and then released, the mass does not keep its shape but falls apart, and slips thru the opened fingers rather easily. The weaker the flour the softer its feel, and the better it keeps its shape after having been grasped tightly, and the less easily it slips thru the opened fingers. Strong flours have a creamy tint, while the weaker flours vary from a very delicate cream color to white, and even to grey—but it is better to beware of a grey flour for any purpose.

For a good many years now, strong flours have been usually preferred for bread, while the weaker flours have been preferred for pastries. This was not true in the earlier history of this country when the wheat grown was universally winter wheat, and no doubt our foremothers made excellent bread as well as pastries from their soft wheat flour—the one kind available.

It is very interesting that within recent years several laboratories[8] in this country have proved that excellent yeast breads can be made from soft-wheat flours, and the writer thru her own ex-

[8]Olson, How to Make Bread from Soft Wheat Flours, (1912), Agricultural Experiment Station, Pullman, Washington.

Davis and Cline, How to Make Good Bread from Missouri Soft Wheat Flour, (1926), Agricultural Experiment Station, Columbia, Missouri.

Wardall and Fitch, Good Bread from Illinois Soft Wheat Flours, (1927), Agricultural Experiment Station, Urbana, Illinois.

periments has come to prefer a moderately soft flour for bread-making. Olson goes so far as to say

> "It may be surprising to learn that good bread can be made from any brand of flour. The volume or texture of one brand of flour does not necessarily have to be the same but if the flour is well handled it will nevertheless make a well-piled loaf of good texture. Frequently the failure to make good bread has been attributed to the flour. The success or failure to make good bread lies with the method practiced with the individual."

The writer is strongly inclined to agree with this statement, because of successes in making very acceptable yeast breads out of some very questionable flours—one a very soft grey flour, impossible apparently for bread-making, and questionable for other purposes, but from which a light, palatable yeast bread of good texture, tho of poor color, was made repeatedly. Success was due simply to good yeast, correct temperature, and proper treatment of the ingredients. But mind, the writer does not recommend soft grey flours for bread-making!

Figure 4 shows three breads, each made from a different brand of flour. Breads A and B were from two soft-wheat Colorado flours, while Bread C was from a well-known hard-wheat flour. The flour from which Bread B was made is one of whose bread-making qualities some housekeepers have complained. Flavors and textures of these three breads were not identical, but each bread

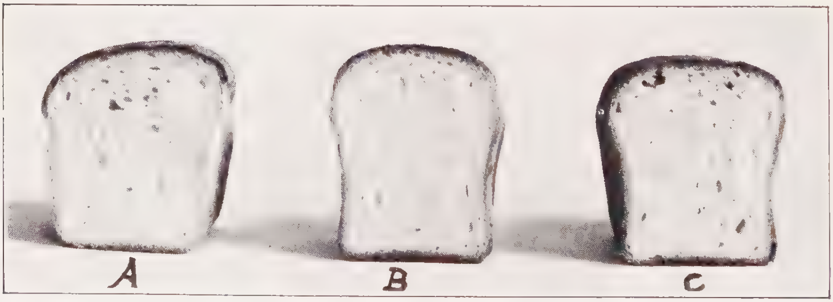

Figure 4.—Showing breads, each made from a different brand of flour—Breads A and B from Colorado soft-wheat flours, Bread C from a well-known hard wheat flour. The gluten content of the flour of Bread C is A of Figures 2 and 3, while the gluten content of the flour of Bread B is B of the same figures.

was excellent in itself—sweet, well flavored and of good texture. Bread C, from hard-wheat flour, differed more from Breads A and B than these differed from each other. It is of much interest that Bread C was made from the hard-wheat flour whose gluten content appears in A of Figures 2 and 3, while Bread B was made from the soft-wheat flour whose gluten content appears in B of the same figures. Evidently, delicious bread does not necessarily depend

upon a tough, tenacious gluten! The writer has no hesitation in stating her preference for Breads A and B.

BEHAVIOR OF SOME LEAVENING AGENTS

Before attempting to study yeast, the leavening agent of "light" bread, it is well to consider two of the simpler leavening agents that the housewife uses. She well knows that she can lighten a so-called "quick" dough, such as griddle cakes, muffins, or biscuits, by means of sour milk and soda, or by means of a baking powder. She knows that the moment she brings sour milk and soda together, or the moment that she wets baking powder, a quick effervescence—an evolution of gas—occurs, and that this gas imprisoned by flour "raises" the dough. If you have never observed this evolution of gas outside of dough itself, you will be interested to try the following two simple experiments for yourself:

SODA AND SOUR MILK.—Into a clean glass* put one-eighth of a teaspoonful of soda, pour one-fourth of a cupful of sour milk over it, and stir thoroly. Note the effervescence which you can hear as well as see. This effervescence is due to the evolution of tiny bubbles of gas and their escape at the surface of the liquid. This gas is carbon dioxide, the same gas that you are breathing out from your lungs thruout life. When the effervescence ceases, taste the milk: it is no longer sour; it has been neutralized[9] by the soda. Soda is an alkaline carbonate, and when treated with an acid, as sour milk, carbon dioxide is promptly set free.

BAKING POWDER.—Into a clean glass put one-fourth of a teaspoonful of baking powder, and add one-fourth of a cupful of cold water and stir thoroly. Since water is transparent, you will more easily see the bubbles of gas that are formed in this experiment than in the preceding one. As you will readily surmise, this gas, so promptly set free, is also carbon dioxide. Baking powders are dry mixtures of soda and some acidic compound. When water is added both dissolve and mutually neutralize each other, and in so doing carbon dioxide is promptly set free from the soda.

A moment's reflection now will tell you that had flour been present also in each glass, then, on addition of sour milk to the contents of the first glass, and water to the contents of the second, the flour in each case would have caught the gas as soon as it was formed: by means of its sticky gluten it would have imprisoned the carbon dioxide, and a lightened dough would have been produced.

If you are interested to try to catch the gas, just repeat these two experiments with the modification that you put one-eighth of

*Use tumblers or jelly-glasses for these experiments.

[9]Goldthwaite, Potatoes from the Housekeeper's Standpoint, Part III, Colorado Agricultural College.

a cupful of flour into each glass, and stir, before as well as after, adding the liquid. Notice the texture of each dough so produced. How does it differ from a dough made by merely stirring flour and water together? If you are not quite sure about this point, just stir a little flour and water together to make a dough for comparison.

STUDY OF YEAST

Having learned the important practical fact concerning two of our common leavening agents, that by proper treatment they each promptly produce carbon dioxide which we utilize in "quick" doughs, let us turn our attention to yeast, the leavening agent "whereby bread is rendered light, porous, spongy."[10] Yeast does not do this promptly; its action is slow. True, yeast produces carbon dioxide, but it does this from its food while living and while growing—for yeast is a living thing; it is not inanimate like the two common leavening agents just considered.

As already indicated, the use of yeast, wild at least, has been known for ages—probably for many centuries before the leavening power of sour milk and saleratus (a substance akin to soda, produced from wood-ashes, soda is a later thing), was discovered. The use of baking powder appeared about the middle of the nineteenth century. But in spite of the antiquity of the use of yeast, any real understanding of what it is and the way in which it raises dough, are matters of comparatively recent years; they are some of the far-reaching results of the marvelous scientific researches of the great French chemist-bacteriologist, Pasteur, (1822-1895).

THE YEAST PLANT.—As a result of Pasteur's researches and the researches of many other scientists, it is now known that yeast consists of myriads of tiny plants—plants very different from those which we know best. In form, a single yeast plant is merely a tiny round cell, about .003 of an inch in diameter. In color as you would readily guess, it is white or translucent—something like that spectral plant of the summer and autumn woods, Indian pipe.

THE GROWTH OF YEAST.—Yeast grows by merely multiplying its cells; this it does by a process of budding, which can be watched under a high-powered microscope. From the side of a yeast cell is seen slowly appearing a tiny bud, or baby cell, which gradually reaches the size of the original or parent cell. Then from the side of the new cell in turn appears another bud, and so on continuously if conditions are kept right for growth. These parent and bud cells remain united for a longer or shorter time, depending upon conditions, thus forming a more or less branched chain-like mass

[10]Century Dictionary.

of cells. For this growth process, yeast, like other plants, needs moisture, food, air and warmth; but unlike most other plants it does not need light.

THE FOOD OF YEAST.—For food the yeast plant needs (1) sugar and (2) the substances necessary to form new cells: Nitrogenous compounds and certain mineral compounds—especially, soluble ones of potassium, calcium, magnesium and phosphorus. Yeast finds all these necessary foods in wheat flour; hence, its ready growth therein. Potato or the water in which potatoes have been boiled, is rich in some of these compounds, hence the reason why potato is sometimes used in bread-making.

Among the sugars so essential to the life-process of yeast, are certain so-called simple sugars, especially glucose. Such sugars, yeast proceeds at once to use, and in so doing breaks them down into various other compounds, but finally into alcohol and carbon dioxide which it excretes. As you already know, it is this carbon dioxide made on the spot by yeast and caught within the sticky gluten of the dough, that "raises" our bread. Jago[11] says

> "The splitting of sugar into alcohol, carbon dioxide . . . . . and other bodies is more or less a respiratory action. That is, its object is the procuring of oxygen, which is required by the yeast plant. It is this capacity of thus decomposing sugar for respiratory or breathing purposes which distinguishes yeast and makes it useful in breadmaking."

It should be explained that ordinary sugar is so complicated in the structure of its molecule, that the yeast plant can use this sugar only indirectly for food—not until it has been broken down into the two simpler sugars, glucose and levulose; this is readily accomplished by means of a certain substance, invertase (an enzyme),* that accompanies yeast.

Before attacking any sugar for its oxygen, yeast always uses any free oxygen to which it has access, such as the oxygen of the air which has been incorporated into the dough during the kneading process; hence, a reason for folding dough over, thus imprisoning air while kneading bread. When the yeast plant becomes surrounded by its own respiration products—alcohol and carbon dioxide—it becomes stifled, unable to continue its growing process until the excess of these products is in some way removed. Hence a logical reason for the frequent kneading of dough, since by this process such excess is allowed to escape and fresh air is again incorporated into the dough; it is unnecessary to explain that alcohol evaporates very readily when exposed to the air, and the gas carbon dioxide only needs the opportunity to make its escape also.

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[11]Jago, Introduction to Breadmaking, p. 71.

*The word enzyme comes from the Greek words *en*, meaning in, and *zyme*, meaning leaven.

The necessity of nitrogenous compounds as food for the growth of the yeast plant should be emphasized. Since nearly 63 percent of the yeast cell is composed of nitrogenous matter, its necessity for the healthy growth of new cells is obvious. Such nitrogenous compounds as the yeast plant can use, occur in the moist wheat dough and are eagerly used by the growing yeast cells.

FERMENTATION.—All these yeast-growth processes taken together are known as fermentation. The whole bread-rising process is really a fermentation process. Chemically, it is not unlike the fermentation that occurs in one of your choice cans of fruit that "works." Some way, in putting up that fruit you were not quite careful enough in the sterilization process, and so a bit of "wild" yeast from the cells or the spores, floating around in the air, got imprisoned in that particular can; therein, it found desirable food and, if the temperature was right, proceeded to grow. You became aware of its presence when fermentation had proceeded far enough to produce sufficient carbon dioxide to be seen as tiny bubbles, or to otherwise make its presence known. Such wild yeast is descended from the wild yeast caught in the wet dough "cakes" of humanity's long past, and thru which humanity finally learned to make fermented or leavened bread.

THE TEMPERATURE DESIRABLE FOR YEAST GROWTH.—As already indicated yeast, like other plants, needs not only moisture, food and air, but also warmth for its life processes. The careful experiments of scientists show that it thrives best between 77 degrees and 95 degrees Fahrenheit. The optimum temperature for bread-making is 84 to 86 degrees Fahrenheit—the temperature of a rather warm summer day. With decreasing temperature yeast grows less and less rapidly, until at 50 degrees its growth ceases and recommences only when the temperature is again raised. At temperatures above 95 degrees the growth of yeast is weakened until at 140 degrees, if moist, the plant is killed. These facts show clearly why yeast itself should be kept in a cold place, why bread-dough needs a moderately warm place for rising and why it should never be allowed to become chilled. Neither should bread-dough be allowed to become too warm during the rising process; bacteria, if present, are favored by the higher temperatures and may cause sour bread.

COMMERCIAL YEASTS.—At the present time yeast is found in market in two forms: Compressed yeast and dry yeast. Both forms have advantages and disadvantages. Compressed yeast consists of a mass of the microscopic plants, mixed with some form of starchy material, pressed into a compact cake, and protected from the air by tinfoil. Such yeast, being moist needs to be kept well chilled that the plants may remain quiescent. If so kept, it will remain in good condition several days or even a week. Otherwise it should

be purchased as needed. Compressed yeast should be slightly creamy-white in color, and should break or crumble rather sharply. If much discolored, or much softened, or mouldy, it should not be used. When crumbled into a liquid of proper temperature, and proper food materials for yeast growth are added, compressed yeast begins to grow very promptly, and therein lies its great advantage for the bread-maker.

Dry yeast consists of a mass of yeast plants well dried in a batter consisting largely of cornmeal. Such yeast, in a very dry cool place will keep a long time. Dry yeast is slow in beginning action, since it must be thoroly soaked up before the tiny plants are in condition to begin growth. However, dry yeast is cheaper than compressed yeast, and since it keeps so well, many women find it especially advantageous, particularly those who live far from market.

SOME YEAST EXPERIMENTS.—After this discussion of what yeast is, its necessary food, and its conditions of life and growth, it is easy to foresee that many a wide-awake housekeeper will be interested to try some simple yeast experiments in her own kitchen —some experiments that will help her to understand better the conditions for growth of that infinitesimal but very important little white plant. For this purpose, sterilize six glasses with boiling water, fill each one-fourth full of water, and when cooled till lukewarm, crumble into each glass one-eighth of a cake of compressed yeast, then proceed with each glass as follows:

1.—To the first add one teaspoonful of sugar; shake gently till dissolved.

2.—To the second add one teaspoonful of glucose and shake likewise.

3.—To the third add one tablespoonful of flour; stir till smooth.

4.—To the fourth add a tablespoonful of cooked potato, freshly mashed; stir.

5.—To the fifth add a teaspoonful of salt; shake gently till dissolved.

6.—Leave the sixth glass containing water and yeast only.

Now place all these glasses on a tray or small board, cover over, and set in a moderately warm place (84 to 86 degrees Fahrenheit) for some hours. Inspect each glass every half-hour or so and notice in which ones effervescence occurs. This will soon be quite evident in the sugar, glucose and flour glasses. If it is slow in appearing in the potato glass, start the action by adding a very little sugar. Notice that no evolution of gas appears in the fifth and sixth glasses; none appears in the fifth because common salt (sodium chloride) contains no element that yeast can use for food; none in the sixth because it contains no food for the yeast. Effer-

vescence occurs in the first four glasses because each contains yeast foods.

It is a very interesting scientific fact that not only is common salt not a yeast food, but it actually inhibits yeast growth even in the presence of desirable food. To observe this inhibiting action of salt, add to the sugar glass in which yeast is growing vigorously, a teaspoonful of salt and shake gently till it is entirely dissolved; then watch the slowing down of the fermentation; you will be interested.

EFFECTS OF TEMPERATURE CHANGES ON YEAST GROWTH.—In these experiments you can also observe the effects of changes of temperature on yeast growth—a very important consideration in bread-making. For this purpose, chill down your glucose and flour glasses by setting them on ice, or snow if available, or in cold running water; gently shake the contents of each glass occasionally until thoroly chilled, noting as you do so the slowing down of the effervescence till it practically ceases. When that point is reached, arrange to let these glasses warm up gradually, gently shaking as before. As the contents warm up fermentation begins and gradually increases till at 84 to 86 degrees Fahrenheit, a vigorous fermentation is again going on. Continue warming up; finally fermentation ceases altogether; the yeast plant is now dead.

SOME CONCLUSIONS FROM YEAST EXPERIMENTS.—Obviously, from these simple experiments with yeast, the wide-awake housekeeper will draw a number of conclusions concerning the life and growth of that little plant, and consequently concerning the making of bread. She has verified for herself certain important facts:

1.—The yeast plant thrives on wheat flour, sugar, glucose and potato.

2.—Salt inhibits the growth of the yeast plant.

3.—Cold inhibits the growth of the yeast plant.

4.—Warmth up to a certain point favors the growth of the yeast plant.

5.—Too high a temperature kills the yeast plant.

Many housekeepers will be interested to do these experiments with dry yeast. This is done by merely substituting dry yeast for compressed. Fermentation will occur just the same, only a much longer time is necessary for it to begin.

EFFECTS OF NON-ESSENTIAL INGREDIENTS ON BREADS

Earlier in this bulletin it was pointed out that three fundamental ingredients—water, flour, and yeast—are essential in making "light" breads, but that the other three ingredients commonly used—salt, sugar, and fat—are non-essential to the main problem. Good-tasting bread, but of rather coarse texture, and somewhat tough, can be made from the essentials only; however, each one of

the non-essentials modifies flavor, or texture, or both, and if not used in excess, does improve the quality of the final product.

In the simple experiments with yeast just completed, we have drawn some important conclusions concerning the behavior of that tiny plant with wheat flour, and with two of these non-essentials. Let us see how these conclusions apply to the problems of bread-making.

EFFECT OF SALT ON BREAD-MAKING.—Of these non-essential bread ingredients, salt is the one we should be most reluctant to discard, regardless of its retarding effect on yeast growth. Bread made without salt tastes insipid to most persons, tho for one who has learned to like the taste of wheat for itself alone, such bread is pleasing. In any case the proportion of salt in bread, as in other foods, should be just enough to "bring out" its natural flavor, not to "cover it up" as an excess of salt does with any food.

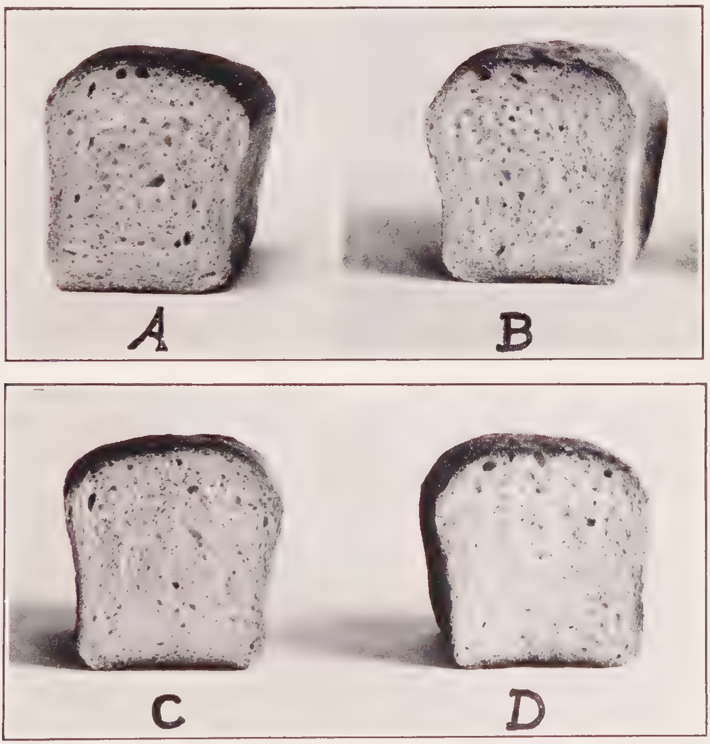

Figure 5.—Breads showing effect of varying proportions of salt on necessary rising periods:

Breads	Salt	First rising	Second rising	Total rising
A	0	3 hrs.	1 hr. 30 min.	4 hrs. 30 min.
B	1 tsp.	3 hrs. 30 min.	2 hrs. 10 min.	5 hrs. 40 min.
C	2 tsp.	4 hrs.	2 hrs. 30 min.	6 hrs. 30 min.
D	3 tsp.	5 hrs. 30 min.	3 hrs. 45 min.	9 hrs. 15 min.

Figure 5 shows four very interesting breads identically made from the three essential bread ingredients but containing varying proportions of salt: Bread A with no salt (for comparison), Bread B with one teaspoonful (4 grams) of salt, Bread C with two teaspoonfuls of salt (8 grams), and Bread D with three teaspoonfuls (12 grams). The effect on the periods necessary for the different risings was most interesting. Tabulated, these periods were as follows:

RISING PERIODS

	First	Second	Total
Bread A	3 hrs.	1 hr. 30 min.	4 hrs. 30 min.
Bread B	3 hrs. 30 min.	2 hrs. 10 min.	5 hrs. 40 min.
Bread C	4 hrs.	2 hrs. 30 min.	6 hrs. 30 min.
Bread D	5 hrs. 30 min.	3 hrs. 45 min.	9 hrs. 15 min.

Examination of this tabulation shows that with an increasing proportion of salt, both the first and second rising periods of each bread were very definitely increased. The last column is simply the sum of the first and second periods, or the total rising period. Note that this total period for Bread D, with three teaspoonfuls of salt, is more than double that of Bread A with no salt; and that the total period of Bread B and of Bread C lie between those of Breads A and D.

Calculated in percentages, the total rising period of Bread B was 26 percent greater than that of Bread A; Bread C 44 percent greater, and Bread D more than 100 percent greater. These retarding effects on the growth of the yeast plant show why bakers consider that salt has a "steadying" effect on yeast fermentation.

In flavor, Bread B was the preferred one of the four. In texture, Bread A with no salt was rather coarse and tough; the others were finer in texture and did not vary much among themselves, but it should be noted that each bread had been allowed to rise till fermentation was complete.

EFFECT OF SUGAR ON BREAD-MAKING.—Sugar, altho a non-essential in bread-making, is a very desirable accessory. As we have discovered in our simple yeast experiments, it is one of the yeast foods. It aids yeast life, thereby reducing somewhat the time necessary for fermentation. If bread is allowed to rise to the limit, sugar may modify both volume and texture, increasing the volume and thereby coarsening the texture. Sugar in correct proportion emphasizes the delicious wheat flavor, and because of the ease with which it scorches it helps to brown the crust, thus imparting to the loaf a pleasing, appetizing color.

Figure 6 shows three breads identically made from the three essential bread ingredients, each without salt, but with varying proportions of sugar—one tablespoonful, two tablespoonfuls, and three tablespoonfuls respectively. The rising periods of these three

breads were limited to the periods necessary for Bread C to attain the proper lightness, with the results that Bread C, the one containing the greatest amount of sugar, was of slightly larger volume, tho not sufficiently so to modify its texture appreciably. Apparently Breads A and B, as well as Bread C, each contained sufficient sugar for their yeast plants; in all three breads any sugar not utilized by the yeast must have helped to flavor the bread. In sugar flavor, either Bread A or Bread B was deemed pleasing, but Bread C tasted artificially sweet. In bread, sugar, so far as taste

Figure 6.—Showing three breads identically made of the three essential bread ingredients, each without salt, but containing one, two and three tablespoonfuls of sugar respectively.

is concerned, should serve merely to "bring out" the natural wheat flavor. The presence of sugar in these breads hastened their fermentation to the extent that they required 15 minutes less time for their total rising processes than did Bread A of Figure 5 which contained no sugar.

EFFECT OF FAT IN BREADS. Fat, especially good butter because of its delicate flavor, is a desirable accessory in breads. Clean, sweet oleomargarine may well be substituted for butter, however. Other clean, sweet fats may also be substituted, but care must be exercised in their use lest they impart an undesirable flavor to bread. Good butter, or good oleomargarine, seems to help to "bring out" the natural sweet, nutty flavor of wheat, while other fats tend to impart simply their own flavors to the detriment of the wheat flavor.

It is well known that flour, fat and water are the essentials of pastry, and that to avoid toughness in pastries the amount of fat used must be liberal in proportion to the amount of water. Fat, then, in pastries renders tender the otherwise tough, flour-and-water crust. So in bread, the effect of fat is to help to make the bread more tender, and hence, to make finer its texture. Breads in which fat has been used, dry out less quickly than those made without fat; hence, fat improves the keeping quality of bread.

Also, fat in bread helps toward forming a brown crust—this is because of the readiness with which fat burns. One tablespoonful of fat to a loaf of bread is the maximum to use; but with other fats than butter or oleomargarine, this amount should be lessened.

PART III. BREAD TECHNIQUE

IDEAL BREAD

The ideal loaf of wheat bread is symmetrical in shape, not lop-sided, nor cracked; it is longer than wide, just wide and just high enough to cut into regularly shaped, attractive slices. Each of its six sides is protected by a tender, crisp, golden brown crust—no side is merely a broken surface. When cut it shows that it has been so well baked that this crust is of a pretty even thickness thruout, and that in its crumb no trace of doughiness exists. This crumb, in color is creamy white—not dead white nor grey! In texture the ideal "light" bread is neither leathery nor crumbly; it is silky, satiny, full of fine holes or air cells, whose walls glisten when the light falls slantingly on a cut surface; it is elastic, so elastic that the cut loaf may be squeezed tightly in the hands and yet when released, regain its normal size and shape with its cell walls scarcely broken only its crisp crust. When sliced, such bread is not crumbly; a slice may be stripped, torn, into shreds, rather than merely crumbled into crumbs; and withal it is tender, it "eats well." No hint of sourness either by odor or taste is detected in this ideal bread—for bread may be light and of tolerably good texture, and yet be sour! Its odor is pleasing, fragrant, inviting; its taste is "nutty," sweet, satisfying; in short, both in odor and taste the ideal bread shows that its constituents were of good quality and well proportioned; its dough was well kneaded, well matured, well risen, well baked; and the bread thereafter well treated.

To make ideal bread is quite possible for any woman. But she must know what good bread is, and she must keep that standard of excellence in mind. She must understand the principles of bread-making—not be a mere follower of recipes; these are very valuable as guides, but back of them are the scientific principles involved, and which the good cook respects even if she does not recognize them as such. She must realize that bread-making demands continual alertness on her part. It is not a job that she can be "miles away" from, and succeed at. Most jobs worth doing, are not! Nor is it a job "so simple a child can do it." It demands intelligence, thought, attention to details; for yeast fermentation neither hastens nor slackens just to suit the convenience of the bread-maker; it is she who controls that by controlling conditions.

Care that everything used in bread-making is scrupulously clean; that the flour used is of good quality; that the yeast used

is fresh and active; that the fat used is desirable; that the mixing and kneading manipulations are carefully, quickly, deftly, thoroly done, and withal that the dough is left slack; that its risings are just sufficient to mature, to "ripen," the dough; that the dough is constantly kept at a proper temperature thruout the mixing, kneading and rising periods; that the oven is well managed. Such are the points in bread-making that need emphasis.

SOME UTENSILS AND ACCESSORIES USEFUL IN BREAD-MAKING

BREAD-BOWL WITH COVER.—Use an earthenware bowl. If possible get one of sufficient size in which to mix and "raise" the desired number of loaves. A four-quart one does nicely for two loaves. Bread dough can more easily be kept at constant temperature in earthenware which retains its heat, than in enamelled or metal ware, which lose heat easily. For the same reason an earthenware cover is better than a metal one; if one that fits the bowl cannot be secured, a large earthenware pie-plate may be used. If a sufficiently large bowl cannot be obtained, an earthenware crock supplied with its own earthenware cover is a good substitute. Or, a bread-mixer may be substituted for either bowl or crock. But before relying upon a bread-mixer, it is better to have sufficient hand practice in kneading, to become acquainted with the proper "feel" of the dough. When this has been accomplished, a bread-mixer of the proper size for the number of loaves to be made, may help materially to lighten the labor of bread-making.

MEASURING CUP.—A glass measuring cup, one-half pint size, with vertical sides and level top (see Figure 1) is preferable to other sizes, materials and shapes. If the cup is of glass, and graduated in fractions, any needed fraction of a cupful of material is easily measured off; but much less easily if the cup is of opaque material. If the cup has a lipped top, a cupful of dry material cannot be measured accurately because the material cannot be levelled off, but if it has a level top the opposite holds true.

QUART MEASURE.—When a large number of loaves of bread are to be made, the necessary amount of flour is more quickly measured out by sifting it into a quart measure (4 cupfuls) than into a half-pint measuring cup. For this purpose, choose one with a level top. For measuring out liquids, the lipped top is handy but is not necessary.

SPATULA.—A limber spatula of good-quality steel, about 10 inches long, is superior to a stiff steel knife for many purposes. It is especially valuable for scraping the curved inner surfaces of bowls.

SPOONS.—A tablespoon of standard size, one-sixteenth of a cupful, should be used for tablespoonful measurements. Sixteen

tablespoonfuls make one cupful. Tablespoonful measurements should always be level, that is, they should be leveled off with the edge of a spatula or knife. If a tablespoon of larger size than the standard is used for such measurements in standard recipes, an error is made.

Likewise, the teaspoon used for teaspoonful measurements, should be of standard size, one-third of a tablespoonful. Three teaspoonfuls make one tablespoonful. Teaspoonful measurements also, should always be level—leveled off with the edge of a knife or spatula.

A wooden spoon is more satisfactory for beating the batter, and stirring the dough than is a metal spoon. Such a wooden spoon should be strong, smooth and shallow, with a handle short enough for the spoon to fit slantingly within the bread-bowl or the bread-crock. If necessary, cut the handle off to the required length. A smooth, strong, narrow, wooden paddle or stirring stick, which may easily be made at home, may be substituted for a wooden spoon.

FLOUR SIFTER.—A strong flour sifter that holds about a quart and turns with a crank, is desirable. Sometimes the sieve in such a sifter gets slightly out of place; it is easily re-adjusted by pushing it evenly upwards till it comes into proper contact with the coiled arms within the sifter.

KNEADING BOARD.—This should be strong, smooth, unblemished and without cracks. Its ends should be so secured, each with a wooden cross-piece, that it cannot warp. When it is to be used for bread-kneading it should be warmed for use—not superficially so, but thoroly. A cold kneading board is ideal for chilling bread dough!

BREAD-BAKING PANS.—The writer has found tin baking pans of the following dimensions the most satisfactory for bread: Length, at bottom 8½ inches, at top 10 inches; width, at bottom 3 inches, at top 4½ inches; depth (vertical) 4 inches. It should be noted, that tho the length and breadth of these pans are substantially those of the bread-baking pans usually found in market, their depth is one full inch more. This depth, 4 inches, is especially recommended because of the support thus afforded a slack bread dough while baking. Of course, it is necessary to explain that to reap the advantage of the 4-inch-deep pan, no more dough should be put into the loaf than would be put into a loaf to be baked in a 3-inch-deep pan. Frequently, bread baked in the shallower pan develops a horizontal crack, which surrounds the loaf more or less completely at the upper edge of the pan—an ideal place, subsequently, for mould. This crack occurs especially, when, just before baking, the loaf has been allowed "to rise to the top of the pan" according to some directions

for bread-making. It goes without saying that bread baked in the deeper, or 4-inch pans, is not supposed to rise to that height—only to the height necessary to ensure good bread. This height will be considered further on.

Bread-baking pans, 4 inches deep, were not to be found in market. Those used by the writer were made to order. Made of good-quality tin, and properly cared for, such pans should last many years. Should housekeepers begin generally to demand such deeper tins for bread-baking, they would soon appear in market, be sure of that—manufacturers always "keep an ear to the ground."

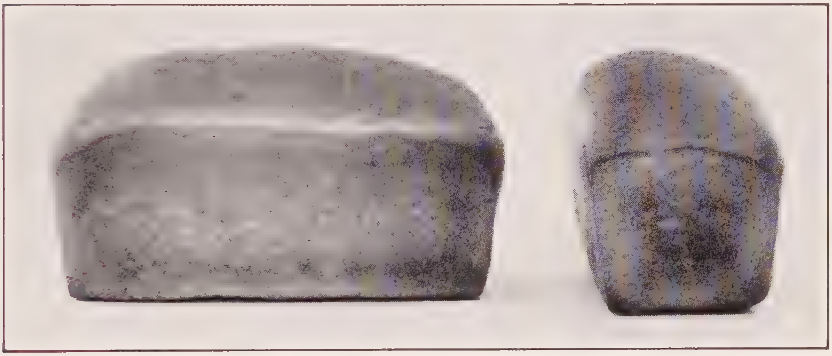

Figure 7.—Showing two well-shaped loaves of bread.

Figure 7 shows two well-shaped loaves of bread, while Figure 8 shows three lop-sided ones. These two sets of breads were identically made regarding constituents, careful manipulation and exact temperature conditions; they differed only in the depth of baking

Figure 8.—Showing three badly shaped loaves of bread.

pan used, and in the last rising. The breads of Figure 7 had risen sufficiently when put into the oven, and they were baked in bread pans of sufficient height (4 inches) to support the slack dough on its further rising in the oven. The breads of Figure 8 had risen

insufficiently when put into the oven, and also they were baked in bread pans too shallow (3 inches) to support a slack dough on its further rising in the oven.

THERMOMETERS.—Two thermometers, at least, are needed; one for the oven and one for the bread dough. If the oven does not already have its own thermometer, an upright standing one to set within the oven, should be provided. Such an oven thermometer can now be purchased for $2.00. To be sure, there are various devices explained in most cookbooks, for determining oven temperatures by the time necessary to scorch flour or bits of paper placed in the oven, and some housekeepers find these devices satisfactory. However, a good oven thermometer is exact, and the bread-maker who relies on one will control her oven more accurately.

Another thermometer more important if possible, for the inexperienced bread-maker at least, is a naked-bulb one for testing liquid and dough temperatures. The writer has failed to find in market such a naked-bulb thermometer planned for cooking purposes, but she has found a short-stem dairy thermometer, which, of course, has its bulb naked, to be a very good substitute. It was purchased for 40 cents.

It is wise always to have the kitchen provided with its own thermometer; preferably a hanging thermometer of the protected-bulb type. Lacking this, the dairy thermometer can be used in its stead. Only, if so used, it must be remembered that a dairy thermometer is very delicate, and hence must hang in a spot where it cannot be easily broken. Always wash and rinse it before testing bread dough with it.

BREAD-CLOTHS AND BREAD-PADS.—To help to keep bread dough at the proper temperature while fermenting, it is well to have one or more cloths and pads made for, and kept for, that purpose only. Each bread-cloth should be made of white outing flannel or of white Canton flannel; two yards is a good length. Each bread-pad should be made of cotton batting covered with white muslin, tied, or quilted loosely together; two yards square is a good size. Each pad should be provided with two detachable white muslin cases, so that as one case is removed for laundering, it may be replaced at once by a clean one. These bread-cloths and pad cases should be laundered often. Wash and boil in good soapsuds, rinse and dry thoroly, fold without ironing, keep in a clean place, and use them only for the purpose for which they were designed. It is unnecessary to add that the pads themselves may be easily laundered when necessary.

BREAD-CABINET.—A cabinet in which dough may be placed for the various rising processes aids materially in keeping it at the de-

sired even temperature. This is especially true if the kitchen is not overheated, or is exposed to drafts. A cold draft on a bread-dough chills it quickly, and a chill interferes at once with yeast fermentation. In lieu of a cabinet, which might be made of a small box, a corner may be preserved on a cupboard shelf for that particular purpose, and serve very well. When needed for use, warm the bread-pads and one of the bread-cloths, line the cabinet or cupboard shelf with one of the pads, wrap the bowl containing the dough in one of the cloths folded to a convenient size, place it on the pad and cover it with the other pad.

BREAD-RACK.—A wire rack, with legs three inches high, is a very desirable support for bread while cooling after being taken from the oven. The old method of wrapping the hot loaves in a clean cloth and letting them remain there till cold, should be obsolete. The better way is to let the bread cool in the air on a wire rack, protected, if necessary, from flies or dust by one layer of a thin white muslin cloth kept for the purpose. By allowing the bread to cool in the air, its flavor is better and it is less likely to become musty later on.

BREAD-BOX.—A large tin bread-box, not air tight, but punctured with one or more groups of tiny holes for ventilation, supplied with a tight-fitting cover—a box that can be washed and scalded frequently, and so kept rigorously clean—is the best receptacle in which to keep bread. Always keep the box with its contents in a dry place, and, if possible, cool.

CLEANLINESS

In order to make good bread, it is absolutely necessary that all utensils and accessories to be used in the process, be scrupulously clean. Hence it is best when about to make bread, to scald afresh with boiling water all utensils to be used in the process. The reason for this cleanliness is to avoid, as far as possible, the entrance into the dough of any bacteria that may cause it to sour, or any that may even survive the baking process and cause "ropy" bread thereafter.

METHODS FOR MAKING BREAD

There are two general methods for making bread: (1) The straight-dough or short-process method, and (2) the sponge or long-process method. The first method may be carried out in from 4 to 6 hours, while the second requires from 20 to 24 hours. This difference in time depends essentially upon 3 factors:

1.—The proportions of yeast used, this being more in short-process bread than in long-process bread.

2.—The thickness of the medium in which the yeast is allowed to grow, this being a stiff dough from the beginning in short-process bread; but, at first, only a batter or "sponge" in long-process bread.

3.—The temperature at which the yeast growth or fermentation is allowed to proceed, this being higher in short-process bread than in long-process bread.

The straight-dough or short-process method is the one commonly employed at the present time by bread-makers who are able to procure compressed yeast often enough to meet their needs. The sponge or long-process method is the method commonly used with dry yeast, and hence is the one found most satisfactory and convenient for many housekeepers. It is the method used by our foremothers when yeast was home prepared and dependent for its keeping qualities not only on a cool storage place, but also, in its preparation, on a rather liberal use of hops to prevent later putrefactive fermentation. Then, to avoid the taste of hops in the bread, a comparatively small amount of yeast was added to a rather thin batter or "sponge" within which the yeast plants might multiply till this sponge was sufficiently "light" to give promise of good bread.

Combinations of these two general methods of making bread are often used: One, leading to a sponge, straight-dough bread; another, leading to a straight-dough, long-process bread. It is hardly necessary to add that such combinations depend upon the proportions of yeast used and upon the stiffness and temperature of the medium in which it is allowed to grow or ferment.

STANDARD PROPORTIONS OF INGREDIENTS FOR BREAD

In order to make clear the two general methods of making bread, it is well to apply them to some standard recipe, for bread. As is well known, bread recipes given by different authorities vary much, especially in the proportions of the non-essential ingredients. Like others[12], the writer has found the following proportions of ingredients a good standard recipe for one loaf of bread:

Water, 1 measuring cupful;
Sugar, 1 tablespoonful, level;
Butter, 1 tablespoonful, level;
Salt, 1 teaspoonful, level;
Yeast, amount and kind depends upon method to be used; for straight dough, short process, one-fourth cake of compressed yeast;
Flour, sifted, three measuring cupfuls—less if possible, more if necessary;

[12]For example, Hunt and Wessling, Bread and Bread Making in the Home, Farmer's Bulletin 807, U. S. Dept. of Agriculture.

Temperature, depends on method to be used: for straight dough short process, 85°-86°, not higher.

Obviously, these amounts for one loaf of bread are easily doubled, tripled, quadrupled, etc., according to the desired number of loaves.

It should be noted that the primary unit of this recipe for one loaf of bread is the one cup of water, that being the measure of water, or "wetting," allowed for one loaf of "light" bread when baked in a bread pan of the dimensions already described in this bulletin. It should be explained that this "wetting" need not necessarily be water; that it may be half water and half milk, or all milk. The milk used may be sweet whole milk, or sweet skimmilk. If of whole milk the proportion of butter should be lessened. Any milk to be used in making bread, must first be scalded and used as soon as luke warm; if this precaution is not taken, the milk is very likely to sour during the fermentation period. In this bulletin it is assumed that water is the "wetting" used.

The amount of flour which one cupful of water will take up, depends upon the flour, and also upon the manipulator, fortunately or unfortunately. The texture of the bread is best when the dough therefor is well kneaded, but yet is left as slack as it can be handled. For this condition, the proportion of sifted flour to a cupful of water is not far from three level cupfuls, and it may be slightly less if the manipulator is very skillful. Bread-makers often err in making bread-dough too stiff—one of the ways to produce a crumbly bread.

FLOUR MEASUREMENTS

The flour to be used in bread-making should always be freshly sifted, then measured, never merely dipped by cupfuls from its container and emptied into the bread bowl as wanted; that is a perfectly good way to add too much flour. Sift and measure the required amount of flour by one of the two following methods:

1.—Place the measuring cup in a clean, dry basin or pan; sift flour directly into the cup till it is heaped up; then tap it gently three times with the spatula, level it off by pushing off the excess of flour with the spatula blade so held that its edge scrapes the cup's rim. Transfer this measured cupful of flour to another basin large enough to hold all the required amount of flour. Continue in this manner to sift and measure off cupfuls of flour till a sufficient number have been prepared. Experiment shows that when flour is sifted and measured in this way, the various cupfuls are of practically identical weight. Hence, the method in skillful hands, is almost as good as actually weighing out the flour. No woman needs

the suggestion that if a large number of loaves of bread are to be made, it may be worth while to substitute for the measuring cup a quart measure, whereby four cupfuls of flour may be measured out at one time.

2.—Sift a larger quantity of flour than will be needed into a large, clean, dry basin or pan. With a tablespoon pile lightly enough of this sifted flour into the measuring cup to fill it heaping full. Tap the cup gently three times with the spatula, and proceed as in the preceding directions. Experiment shows that this method is a little less accurate by weight than the preceding one.

STRAIGHT-DOUGH OR SHORT-PROCESS BREAD

Let us now apply our one-loaf bread recipe to a sufficient amount of straight dough for a two-loaf baking. It is rarely economy to make only one loaf of bread at a time, and it is usually wiser to make more than two. However, consideration of a two-loaf baking will do for our present purpose.

For two loaves of bread, prepare six cupfuls of sifted flour, measuring it out by one of the two methods described. It is sometimes well in bread-making to prepare an extra cupful, to hold in reserve for possible need; experience will tell whether or not that is necessary. Put the sifted measured flour where it will get warmed thru, if it is not so already. If flour is kept in a very cool place, the required amount should be prepared some hours ahead of the time it is to be used, that it may be getting thoroly warm. Test its temperature by inserting the bulb of the dairy thermometer within the mass of flour and letting it remain there some minutes. For the straight-dough method the temperature of the flour should be at least 80 degrees, but not above 85 degrees F.

Heat a sufficient amount of water to scald the necessary utensils. Let the cover plate, anyway, remain in the hot water till needed. Empty the bread-bowl of water, shaking it out, wiping the outside only. Transfer to the bread-bowl two level tablespoonfuls each of sugar and of butter, and two teaspoonfuls of salt. Add a cupful of boiling water. When the butter is melted, add a cupful of cold water, previously boiled and cooled if there is any question regarding its purity. Of course it is understood that these cupfuls of water are exactly level full. When the mixture in the bowl is cooled to 90 degrees, crumble one-half cake of chilled compressed yeast into it; this is in the proportion of one-fourth cake of compressed yeast to one cupful of water; double this amount of yeast if it is desired to complete the bread-making process more quickly. With the wooden spoon, rub the crumbled yeast against the bottom of the bowl till it is rubbed to a smooth paste, then stir thoroly the contents of the bowl. Some prefer to rub the yeast smooth in a

small amount of water in a cup by itself, and then add the resulting yeast paste to the contents of the bowl. This may be done, of course, but if so, allowance for the amount of water to be so used, should be made previously: otherwise, an error in the total amount of wetting is introduced, and the recipe is not followed exactly.

After adding the yeast and stirring thoroly, gradually add the prepared flour while constantly beating the resulting batter to keep it as smooth as possible. As the mass becomes too stiff for beating, continue to add the flour while stirring the dough carefully till five cupfuls of the six prepared, have been added. At this point it is well to let the dough rest about 15 minutes. Take its temperature by burying the bulb of the thermometer within it to remain while the dough is resting. The correct temperature for this short-process bread is 85 to 86 degrees. Cover the bowl while the dough is resting, and place it in the cabinet. Meanwhile, put the sixth cup of flour on the warm kneading board and spread it out in a thick layer just large enough in diameter to protect the dough to be laid upon it. It is much easier to keep a bread dough slack, when kneaded over a thick layer of flour than when kneaded over a thin layer; or than when kneaded in the bread bowl.

When the dough has rested 15 minutes, remove it from the bread bowl to the thick layer of flour prepared for it; then, with the cleanest of clean hands, washed in hot water, quickly, but lightly, knead into it as much or as little of this flour as is necessary to make a smooth but slack dough. In kneading bread-dough, try to do so rapidly but deftly: slip the dough one-fourth the way around each time it is folded over, and at the same instant press down rapidly and lightly two or three or more times with the balls of the hands, squeezing the dough simultaneously, but gently with the spread fingers. Quick, light touches and motions are best. Never press hard. Avoid long kneading, lest the dough get chilled—once chilled, yeast action is slow. The dough has been kneaded enough when it seems elastic, sufficiently elastic to spring back when slightly dented with the finger—when it seems covered with little air blisters. This kneading process should be completed within 10 minutes, and the dough ready for its first rising. Transfer it to the bread-bowl, buttered, and slightly warmed if necessary; butter the top of the dough, and take its temperature or, better, insert bulb of thermometer in the dough to remain during its first rising. It is probably unnecessary to add that it is not necessary that the thermometer remain perpendicular—its position may be as slanting within the bowl as necessary, the bulb remaining downward of course. Remember you are trying to keep the temperature of the dough at 85-86 degrees F., not above! Cover the bowl with its cover

plate slightly warmed; wrap it in one of the folded bread-cloths, also warmed if necessary; set it in the well-padded cabinet, and cover it as closely as necessary with the other pad. This first rising, with the amount of yeast used (one-half cake for two cupfuls of water), and the temperature 85 to 86 degrees closely maintained will probably take from two, to two and one-half hours. Watch the dough closely, especially during the latter half of this period.

It should rise till it seems light all thru, just light enough so that a moderate touch with the finger starts it very gently downwards. This point is exceedingly important in making good bread, for it is the point that indicates that the dough is "ripe," that is, that the fermentation has been carried just far enough to give the resulting bread the desired flavor, just far enough to soften the gluten, and yet retain the desired elasticity of texture. Bread from under-ripe dough is tough—its gluten has not been sufficiently softened by fermentation; from over-ripe dough is very likely to be crumbly, while it may smell and taste more or less faintly sour—due to bacterial action. Prove the toughness of under-ripe dough, and the crumbliness or sourness of over-ripe dough, some time, by baking some unrisen dough, and then some very much over-ripe dough; these two little experiments will well emphasize two conditions to be avoided—under-risen dough, and over-ripe dough—the Scylla and Charybdis between which you must steer.

When the dough is just ripe, it is ready to be molded into loaves. The aim of this process, primarily, is to rid the dough of its excess of carbon dioxide gas, to distribute evenly that which is left, and then to mold the dough into smooth loaves. The expert often does all this simply with well-buttered hands, and without once touching the dough to the kneading board. But the safer method for the inexperienced is to transfer quickly one-half of this two-loaf bread dough to the kneading board which yet has the remains of the sixth cup of flour upon it; rapidly to press the dough down flat to force out the excess of carbon dioxide as completely as possible; then to fold the dough over from back, from front, from one side and then from the other, pressing the dough tightly together after each of these foldings; then quickly and deftly to roll it into a smooth loaf—it will be about the desired width and length if the foldings have been well proportioned. Now place the loaf in a well-buttered, slightly warmed, bread-pan and brush the top of it with melted butter. This rapidity of action is to keep the dough from getting chilled. Repeat this whole process with the other half of the dough. Place both loaves in the bread cabinet or in a moderately warm place where they will not be exposed to a draft; cover the pans with clean paper, or with a thin, clean cloth so supported that it cannot possibly touch the loaves themselves. Let them rise

till the dough just fails to respond to a slight dent made by the finger, and the pan with its load feels a bit light. This rising is very important; it will probably take from one to one and one-fourth hours. When risen just enough, or very slightly under, slip the pans at once into a hot oven, preferably 400 degrees F. Insufficiently risen dough is likely to lead to badly shaped loaves, similar to those shown in Figure 8. Be sure a space is left between the pans in the oven that the heat may circulate freely around them.

If your oven door is fitted with a glass inset, you can easily keep watch of the baking process. In most ovens it is well to turn each loaf within the first 10 minutes, lest one side rise higher than the other. The bread will continue to rise slightly for 15 minutes, then should begin to brown. In some ovens at the end of 25 or 30 minutes, the oven heat should be lowered gradually and the baking continued at a lower temperature. The bread is baked when it is evenly and rather deeply browned, and has shrunken from the sides of the pan. This will take from 45 to 50 minutes or more, depending upon how the oven temperature has been controlled and upon the oven itself. Turn the baked loaves out upon the bread-rack, and if they are not evenly browned all over, return them quickly to the oven to bake a few minutes longer. Otherwise leave them upon the bread-rack to cool. Do not cover unless it is necessary to protect them from flies or dust.

From the time that the dough was ready for its first rising, till the bread is out of the oven, this straight-dough method will take from four to six hours, depending upon the dough temperature it has been possible to maintain. As already indicated, this time can be shortened by increasing the proportion of yeast used.

As repeatedly emphasized, it is important in straight-dough short-process bread to keep the temperature of the dough at 85 to 86 degrees, but the temperature should not be allowed to go higher than that. This is because of possible bacterial action which is likely to occur at the higher temperatures. Yeast acts more quickly than bacteria, and at lower temperatures, hence the desirability in straight-dough bread of using enough yeast and of keeping the temperature at just the right point to push the whole process thru promptly.

With some flours, a third rising of the dough produces a bread of somewhat finer texture than that produced when only two risings are allowed. If a third rising is desired, then after a slight second kneading, which may be done on the kneading board, or in the bread-bowl, allow the second rising to take place in the bread-bowl similarly to the first rising. When the dough has now risen to the point at which a slight dent made with the finger barely remains, make it into loaves and proceed as heretofore described.

MODIFICATIONS OF THE STRAIGHT-DOUGH METHOD FOR BREAD-MAKING

A STRAIGHT-DOUGH, SPONGE METHOD.—The straight-dough method of bread-making is easily modified, if desired, to a straight-dough, sponge method. For this purpose, lessen the amount of yeast to one-sixth of a cake of compressed yeast to each cupful of water, and proceed according to the straight-dough method till one-half the total amount of water to be used has been beaten into the batter; beat the batter thoroly, cover it closely, and set it in the bread-cabinet till the "sponge" is foamy. This will probably take about an hour. When this sponge is foamy, add the remainder of the flour as necessary to make a slack dough and continue according to the straight-dough method. Obviously, this method takes more time than the simple straight-dough method.

A STRAIGHT-DOUGH, LONG-PROCESS BREAD.—The straight-dough method of bread-making is also easily modified to a straight-dough long-process or over-night method. Briefly, the changes to be made are (1) to lessen the amount of yeast used, and (2) to allow the dough to rise at a lower temperature for a longer period of time. Proceed as follows: For each cup of water used, lessen the amount of yeast to one-eighth of a cake or even less. Arrange to knead the dough and to carry out the whole process at 68 to 70 degrees, instead of at 85 to 86 degrees. Knead the dough till smooth and elastic, and set to rise between nine and ten o'clock at night. Cover properly, arranging to keep the dough at 68 to 70 degrees till morning. When light, as it should be early in the morning, knead into slack loaves continuing according to the straight-dough method.

LONG-PROCESS OR SPONGE BREAD

This is the second of the two general methods for making bread. It is usually carried out with dry yeast or with home-made liquid yeast, and is an over-night process. With dry yeast modify the standard recipe for one loaf of bread as follows:

To each cupful of water, instead of compressed yeast, use one-fourth of a cake of commercial dry yeast. For two loaves of bread, crumble one-half cake of this dry yeast into one-fourth cupful of lukewarm water, and let it soak 20 minutes. To the remainder of the water needed (one and three fourths cupfuls), add the other required ingredients according to the straight-dough method until one-half the sifted and measured required amount of flour has been added, but keep the temperature at 68 to 70 degrees instead of 85 to 86 degrees. Beat the resulting batter or "sponge" very thoroly, cover and set it in the bread-cabinet overnight, making arrangements to keep it at 68 to 70 degrees till morning. When "light" and foamy, as it should be in the morning, add the remaining flour till

an elastic, slack dough is formed, and continue according to the straight-dough method.

A nice modification of this method is as follows: Soak the dry yeast 20 minutes at night in one-half the total amount of water, lukewarm, to be used; cautiously add sifted and measured flour till one-fourth the amount of flour necessary has been added, meanwhile beating constantly to keep the batter smooth. Cover properly and let it rise at 68 to 70 degrees over night. When light in the morning, put the required amounts of sugar, butter and salt together in a small bowl, add the needed other half of water, boiling hot, to this mixture, and when it is cooled to 100 degrees add it slowly, beating constantly, to the risen sponge. Take the temperature of the resulting mass—it should be about 85 degrees. Slowly add the remainder of the flour (warmed) necessary to form an elastic slack dough, and continue according to the straight-dough method.

Liquid Yeast

In long-process bread, either liquid or dry home-made yeast may be substituted for the commercial dry yeast. The writer has found the following old recipe for liquid yeast, a reliable one: Steep one-half cupful of loose hops in one quart of boiling water in an enameled kettle, five minutes. Mix together one cupful of flour, one-fourth cupful of sugar, and one tablespoonful of salt. Strain the hop liquor, and pour it boiling hot into the flour mixture, while stirring the latter constantly. When lukewarm, add one cake of compressed yeast rubbed to a fine paste in one-fourth cupful of lukewarm water; or, one cake of commercial dry yeast thoroly soaked in a like amount of lukewarm water; or, one cupful of a good liquid yeast. Set the mixture in a moderately warm place till fermentation is active. Transfer it to a well-scalded earthenware jar or crock of sufficient size to allow for fermentation, cover with well-scalded earthenware cover, and keep it in a cool place. One-half cupful of this liquid yeast should equal in fermentation value, one cake of commercial dry yeast.

An Ideal Loaf of Bread

Figures 9, 10, 11 and 12 show an interesting sequence of pictures of the same loaf of bread a loaf meeting very closely the requirements of the ideal.

Figure 9 shows the uncut loaf; Figure 10 the loaf with a few slices cut off; Figure 11 the cut loaf while being tightly squeezed in the hands to test its elasticity; Figure 12 the loaf released thereafter. Note in Figure 9 the nearly symmetrical shape of this loaf of bread, and its well-colored crust unblemished by such cracks as

are shown in the breads of Figure 8; note in Figure 10 the attractive, regular, appetizing slices into which this symmetrical loaf cuts; note its perfect elasticity as shown in Figures 11 and 12—tightly squeezed in Figure 11, its shape regained in Figure 12 with

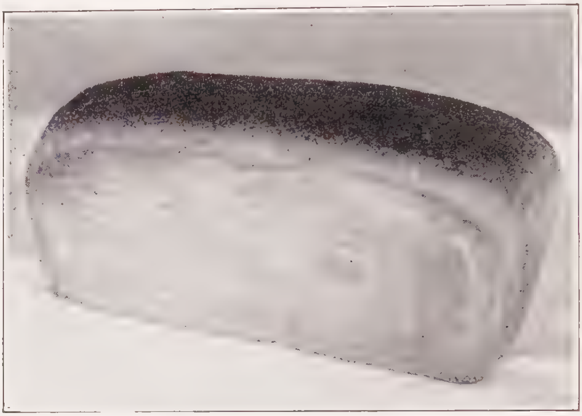

Figure 9.—Showing a well-risen, symmetrically shaped, well-baked loaf of bread.

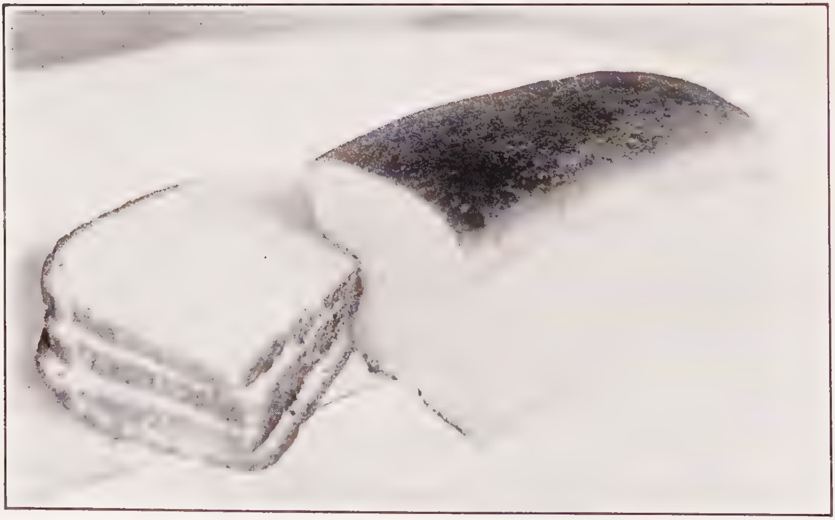

Figure 10.—Showing the loaf of Figure 9, cut.

little if any breaking of the cell walls, only slight cracks in its tender, crisp crust. This loaf of bread, in symmetry of shape, good color of both crust and crumb, excellent texture, inviting odor, and delicious flavor, like many others made in the course of these ex-

periments, met very well the exacting requirements of the ideal loaf of bread.

Figure 11.—Showing the cut loaf of Figure 10 while being tightly squeezed to test its elasticity.

Figure 12. Showing the loaf of Figure 11, released.

It was made by the straight dough or short-process method, and of Colorado soft-wheat flour.

Bulletin 345 May, 1929

THE AUSTRALIAN SALTBUSH

Its Composition and Digestibility

An Extension of Bulletin 135

By Wm. P. Headden

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THE AUSTRALIAN SALTBUSH

Atriplex semibaccata

By Wm. P. Headden

At one time this plant was thought to hold out considerable promise as a forage which could be produced under very unfavorable soil conditions and also with a very small rainfall. These are desirable properties provided the forage proves agreeable to the animals required to eat it, and it nourishes them well.

Its manner of growth and the difficulties presented in gathering it are minor points easily met, provided the forage is needed and desired. It was not supposed that it would take the place of alfalfa or any other good forage but simply be a substitute under conditions in which better forages could not be produced. Alfalfa needs a good many inches of water to produce even one good crop in a season, but this saltbush is said to do well with very little water; 4.7 inches is the figure given. Our ordinary forage plants will not grow with so little water. The need of forage plants in parts of this state has been attested for years by the makeshifts resorted to, such as the use of Russian thistles, sand-grass and some native saltbushes.

We have given the composition and digestibility of some of these in earlier bulletins, but this seems not to have helped the people whose interests we had in view. We called this plant, the Australian Saltbush, to the notice of dryland farmers 20 years ago in Bulletin 135 of this station.

Analyses Misleading

There is little value in an analysis alone as is abundantly shown in some of these experiments. We used two analyses, one of a hay, clover and mixed grasses, and one of oat-grass to illustrate this. The analysis of oat-grass, *Stipa viridula*, is in every respect apparently better than that of the hay; protein content is 1.8 times as large as in the hay. The amount of ash is not objectionable, the crude fibre is not excessive and the nitrogen-free extract is only about one-sixth less than in the hay. Mixed hay is a good forage. All stock eat it but they will not eat oat-grass, even green, if they can get anything else at all. Perhaps a better illustration of the unreliability of an analysis is a comparison of "native hay" a mixture of native, mostly meadow grasses, and sedges, corn fodders, and hay made of the native saltbush, *Atriplex argentia*. The analysis of these fodders is here produced.

NATIVE AND SALTBUSH (A. argentia) HAY AND CORN FODDER COMPARED

	Native Hay Percent	Corn Fodder Percent	Saltbush Hay Percent
Moisture	5.13	8.21	5.32
Ash	10.64	9.53	19.28
Ether Extract	3.13	1.55	1.46
Proteins (Nx6.25)	6.98	4.62	9.73
Crude Fibre	31.33	29.85	27.33
Nitrogen-free Extract	42.79	46.24	36.88
	100.00	100.00	100.00

The native hay is considered a good fodder. For sheep we found it moderately good, equal to, but not better than corn fodder. I wish to emphasize the fact that the statements made in this connection refer to results obtained with sheep. Other farm animals digest about the same amount as sheep, still the fodder might agree better with other animals. The sheep that we fed on this fodder lost very rapidly. If the rate of loss could have been maintained, the sheep would have lost more than their original weight in 90 days.

Coming back to our analyses, I think that the general judgment based on analytical results would be in favor of the saltbush hay. It is true that the ash is high, nearly twice as high as in the native hay. It is, however, only about two-thirds as high as in dried beet leaves, and the proteins (Nx6.25) are twice as high as in the corn fodder. The crude fibre is lower than in either of the other two and the nitrogen-free extract is only lower by 10 percent than in the corn fodder. These are the usual groups into which we divide fodders. We may add that neither of the plants is known to ever contain anything poisonous to stock as is sometimes the case with green sorghum.

The results of our feeding experiments bear no relation to the compositions set forth in these analyses. The native hay and corn fodder gave equally favorable results, a gain of 3.5 pounds in 5 days. This saltbush hay caused a loss of 9 pounds in 5 days. For our present purpose we consider only the analyses and the results. The native hay and the corn fodder were more than maintaining the animals but they were actually starving on the saltbush in spite of its apparently better analysis.

These are not the only instances that might be given. If Minnesota Early Amber sorghum and corn fodder be compared in the same way, we shall have the following:

	Sorghum Percent	Corn Fodder Percent
Moisture	5.75	8.21
Ash	8.17	9.53
Ether Extract	1.55	1.55
Protein	5.80	4.62
Crude Fibre	23.26	29.85
Nitrogen-free Extract	55.47	46.24
	100.00	100.00

Here we have two quite similar plants and the composition is not so very unlike. The sorghum is the richer in proteins and easily soluble carbohydrates, or nitrogen-free extract, and lower in crude fibre. The feeding results with these samples were: Sheep fed on sorghum lost 7.5 pounds; fed on corn fodder they gained 3.5 pounds, a difference of 11 pounds of flesh in 5 days. The coefficients of digestion are not apparently wide enough apart to account for the results obtained, and by chance, the same sheep were used in the two series of experiments and during the same season, so they were of the same age and the idiosyncrasies of the animals were the same The only explanation that we have to offer is the evident one, expressed by the loss of 7.5 pounds of flesh, to-wit: The sorghum was lacking something needed by the sheep. We say it did not agree with them, but the corn fodder did. Both of these fodders were in excellent condition when fed and there was no mature corn in the fodder. What principle was lacking in the sorghum we do not know. There were no other signs of any injurious effect upon the sheep.

It is a question whether the ordinary analysis, such as is quoted here, is really sufficient to give more than a general idea of the possible value of a fodder. The coefficients of digestion, at least some of them, perhaps the most of them, may be good, but the testimony of the animals experimented with may be adverse. Our experiments with the hay of a native saltbush illustrates this.

The saltbush was *Atriplex argentia*. The analysis of this hay gave proteins (Nx6.25) 9.73 percent, nitrogen-free extract 36.88 percent, crude fibre 27.33 percent. The average coefficients of digestion found for three sheep were, for protein, 66.35; nitrogen-free extract, 49.16; fibre, 8.29. The same for alfalfa are proteins, 72.54; nitrogen-free extract, 72.89; fibre, 49.93. The consumption of proteins in the two cases, saltbush and alfalfa, was very nearly the same so that the amounts of proteins digested were also nearly the same—1309 grams with alfalfa and 1096 grams with saltbush, but the feeding results were very different. The sheep fed alfalfa gained 9 pounds and those fed saltbush lost 8.5 pounds.

The question arises: Do the differences in the observed coefficients of digestion and the composition of the fodders give us the explanation for the results? Two points are fixed with reasonable certainty—the amounts of the protein, etc., used and the final weights of the animals. The amounts of protein and nitrogen-free extract digested were: Three sheep fed on alfalfa; protein, 1308 grams, nitrogen-free extract, 2544 grams. Three sheep fed on saltbush; protein, 1096 grams, nitrogen-free extract, 3012 grams.

The sheep digested 212 grams less protein and 468 grams more nitrogen-free extract when feeding on saltbush hay than when feeding

on alfalfa, but of crude fibre the sheep feeding on saltbush hay digested 1534 grams less than those eating alfalfa hay. If our analytical and experimental results are criteria, then the alfalfa hay is better than saltbush hay because its crude fibre is digestible while that of the saltbush is indigestible. The animals eating alfalfa gained flesh while those eating saltbush lost. The legitimate inference is that the important factor is neither protein nor nitrogen-free extract but the crude fibre. This would be difficult to believe.

Our Criteria Unsatisfactory

Assuming that these three parts of the fodders contain all and the only factors that participate in any essential way to the nourishing of the animals, the legitimate inference is, comparing alfalfa and saltbush hay, that the crude fibre must be the important factor in producing the bad results obtained in the case of the saltbush or the good ones in that of the alfalfa hay; but in comparing alfalfa and sorghum, the inference is that the proteins are the important factors. With the digestion of large amounts of proteins we have a good gain; with small amounts, a decided loss, but with corn fodder we have a satisfactory gain, 3.5 pounds, with the digestion of only one-sixth as much protein as they digested when fed saltbush, and one-seventh as much as when fed alfalfa. The nitrogen-free extract digested when corn fodder was fed was considerably less than with either of the other three fodders and the crude fibre was for the three sheep only 130 grams more than was digested when they were fed sorghum. The same three sheep were used in these experiments. The cheapest gain was made with the corn-fodder.

In regard to the water consumed, the saltbush caused the animals to drink about twice as much water as when fed other fodders. How much weight is to be attached to this factor in judging of its value I do not know, but no excess of water was drunk when sorghum was fed, when the loss was likewise 8.5 pounds in 5 days. The proteins digested when sorghum was fed totalled 301 grams by the three sheep. When saltbush was fed, 1098 grams were digested and the loss was nearly equal, 8.5 against 7.5 pounds. The data obtained by analyzing the fodder and determining the coefficients of digestion are not adequate to explain the results obtained. All that we can state is that alfalfa and corn fodder are good fodders for sheep and that sorghum and this saltbush are not good ones for sheep.

So far we have omitted two groups, the mineral constituents or ash, and the ether extract. The ash is highest in the saltbush and next in the alfalfa, and about 9 percent each in corn fodder and sorghum. The ether extract is so nearly the same in each that, so far as the

quantity is concerned, we cannot attach any importance to the differences. It does not follow, however, that it is not important.

It seems certain that we have not considered the real causes of the differences in the values of these fodders.

Heat Energy as Criterion

We attempted to find a better explanation in another relation, i. e., in the heat or energy of the fodders. This is no less unsatisfactory. The energy appropriated by the animals was, when fed alfalfa: 30,955,663 small units of heat; corn fodder, 19,424,180; sorghum 25,088,621; and saltbush, 23,149,533. The sheep appropriated more energy from alfalfa and made more gain than when fed corn fodder and the gain is relatively greater with the alfalfa than with the corn fodder, i. e., the energy appropriated from the alfalfa is about 1.6 times that appropriated from the corn fodder while the gain is 2.6 times that made with the corn fodder. This result cannot be wholly due to the energy used for they appropriated more energy with the saltbush and also with the sorghum than with the corn fodder but the animals lost 8.5 pounds in 5 days on these fodders, whereas they gained 3.5 pounds on the corn fodder.

Neither the analyses nor the determinations of the heat or energy values have revealed the actual values of the fodders. The feeding experiments show that alfalfa and corn fodder are good but that sorghum and saltbush are very poor when fed alone.

Sorghum and Saltbush Prepared As Emergency Fodders

The saltbush hay and the sorghum also were gathered as emergency fodders to tide stock over periods of stress. They were fed to animals protected from the weather and made as comfortable as we knew how, but the results show the fodders to be very poorly fitted for the purpose that they were intended to serve. The animals lost flesh rapidly under these favorable conditions. Had they been exposed to cold high winds and snow, it would have been even worse for them.

These are the only fodders prepared with this object in view. Alfalfa, timothy and native hays are out of the question under dry-land conditions. Mixed rations are also not to be considered in connection with these emergency fodders. But alone these will not maintain an animal living under the most favorable conditions for even the few days of a digestion experiment, -12 days in all, 7 days preliminary feeding and 5 days actual observation. It was during these last 5 days that the sheep lost 8.5 pounds when fed these fodders. The animals were actually starving tho they were eating plenty.

The question for our dryland farmer was and still is, what emergency ration can be provided which is better than these. For him alfalfa and the ordinary fodders are out of the question. His choice is confined to what he may be able to grow in sufficient volume to supply his requirements. This was the question we had in view in making these experiments and was the reason for our procuring fodders grown under those conditions and prepared for actual use and not for our special purpose. The results, however, have a much wider significance, but this does not alter the practical fact that saltbush hay and sorghum fodder constitute a starvation diet for sheep. How bad this would be if the animals were exposed to cold, or high winds with rain or snow, the writer has no idea.

It seemed unfortunate that these two fodders should be the ones available to the ranchmen of our drylands, a section in which there is sometimes a lack of pasture except in favorable seasons. The native grasses are nourishing but, like other plants, they can make only little growth with the water available. Further, they are slow in reestablishing themselves when broken up or killed out.

It has been stated that the sorghum used was Minnesota Early Amber, a saccharine variety, but I understand the non-saccharine sorghums are more commonly grown.

Australian Saltbush

We studied the Australian Saltbush, *Atriplex semibaccata*. The reasons for this choice were that it was commended as the best of the saltbushes as a fodder and succeeds with a small amount of water.

With us it grew vigorously; of course, it had plenty of water, and the soil was a rich loam. The dryland soil may be good but the water would be much less than it had in our case. The habit of the plant with us was prone but the diameter of single plants was commonly as much as 7 feet. A diameter of 18 feet is recorded for it. We cut it and made it into hay for our digestion experiments. I do not know what kind of a winter pasture it would have made.

The plant with us was an annual but seeded itself abundantly. These cultural features were not the object we had in view but we grew it for eight seasons on two types of soils and it did well in all cases. We fed it green to a horse with good results, at least the animal seemed to do well on it, tho it was not weighed; also to some (3) old sheep for 3 weeks. These animals maintained their aggregate weight. The digestion experiments were made with sheep going on two years old. The results of these experiments are given in Bulletin 135, Colorado Experiment Station, 1908. The coefficients of digestion found were very good indeed. Compared with alfalfa and native hay, they stand as follows:

	Dry Matter	Ash	Fat	Protein	Fibre	Extract
Alfalfa	63.95	57.67	29.86	72.54	49.93	72.89
Australian Saltbush	60.48	59.64	24.46	84.65	27.30	63.83
Native Hay	50.53	42.52	20.55	62.33	55.56	51.30

The alfalfa was of good quality grown at Fort Collins.

The dry matter of the saltbush is almost as digestible as that of the alfalfa but this tells us only that the animals appropriate almost as much of the one hay as of the other. The ash is both larger in amount in the saltbush and is more freely taken up by the animal. This is not necessarily good, it might be the opposite, but in this case we observed no indication that this was the case. When the plant was fed in the green state, it had a laxative effect at first but this disappeared shortly and the animals did not seem to suffer inconvenience of any sort. The protein is not only very abundant in the hay, 20.6 percent in that used in the digestion experiment, but it has a very high coefficient of digestion, 84.65 against 72.54 for the protein in alfalfa hay, of which it constituted 15.03 percent. The coefficient for the crude fibre is quite low, 27.3, but that for the nitrogen-free extract is fairly high, 63.83. We have put beside these the coefficients of digestion found for a good quality of native hay, which are lower thruout than those for the saltbush. The sheep fed the native hay, whose coefficients are given above, gained 3.5 pounds in 5 days, and on the saltbush 1 pound. The crude fibre is the only group in the native hay having a higher coefficient of digestion than in the saltbush. It should also be noted that, while no sheep in either series lost weight, more than two-thirds of the total gain made when fed native hay was made by a single sheep, the other two making the same gain that two of those fed on saltbush made, while the third animal fed on saltbush neither gained nor lost.

Australian Saltbush Varies Greatly in Composition

The saltbush hay was very good. The plants were cut before many seed were ripe and were cured on canvas in order to save all the leaves. The protein was higher in this sample than any other analyzed. Our samples of this hay made in different seasons varied very greatly in this respect. Some of our samples were the lowest that I found given for the plant and this one was the highest. The plant seems to vary greatly according to the soil in which it is grown but a part of the differences observed may have been due to loss of leaves and other causes. The variation in the composition of the ash points to the soil as having an unusual influence upon this plant. This chlorin, for instance, in the ash of this plant grown on good soil—we can, I think, properly designate it as alkali-free soil—was less than 6 percent, 5.82, whereas in that of plants grown on alkali soils it was 20.8 and

24.33 percent, and the ash in our hay was about 18.0 percent in all of our samples, also in Californian samples, but is given as 13.09 percent in hay grown in South Dakota.*

The hay is not so good as alfalfa hay notwithstanding the high coefficients of digestion for all groups except the crude fibre. On the other hand it is as good as timothy and native hay and decidedly better than the sorghum that we fed.

The details of these data were published in 1908, (Bul. 135, Colo. Exp. Sta.) at which time little or no interest seemed to be taken in the matter and there seemed to be no adequate object for giving the following data, but they present further features of the question which may have value enough to justify their presentation.

DATA ON AUSTRALIAN SALTBUSH. Atriplex semibaccata.
Composition of the Hay and Coefficients of Digestion.**

	Moisture	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	3.645	18.635	1.370	20.600	16.382	39.368
Orts—						
Sheep No. 1	3.610	21.668	1.460	20.820	15.233	37.209
Sheep No. 2	3.595	24.251	1.400	20.310	13.287	37.157
Sheep No. 3	3.485	22.156	1.400	20.500	14.502	37.957
Feces—						
Sheep No. 1	4.560	14.974	2.350	7.940	35.417	34.759
Sheep No. 2	4.525	15,894	2.240	8.090	32.142	37.109
Sheep No. 3	4.820	17.848	2.880	7.750	31.205	35.497

Experimental Data—Sheep No. 1 received 6,577 grams of hay.

	Dry Matter	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	6337.27	1225.62	90.11	1354.86	1077.44	2589.24
Orts	4192.00	942.34	63.50	905.46	662.48	1618.22
Consumed	2145.27	283.28	26.61	449.40	414.96	871.02
Voided	1089.93	171.03	26.83	90.67	404.46	396.94
Digested	1055.34	112.25	-0.22	358.73	10.50	574.08
Coefficients of Digestion	49.19	39.57	....	79.74	2.53	58.85

This animal weighed at the beginning of the experiment 78¼ pounds, and at the end 78½ pounds.

Sheep No. 2 received 7,938 grams of hay.

	Dry Matter	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	7648.66	1479.30	108.76	1635.20	1300.40	3125.00
Orts	2056.32	517.28	29.86	433.21	283.41	792.56
Consumed	5592.34	962.02	78.90	1201.99	1016.99	2332.44
Voided	2195.93	365.57	51.52	186.07	739.26	853.51
Digested	3396.41	596.45	27.38	1015.92	277.73	1478.93
Coefficients of Digestion	60.87	62.00	34.70	84.52	27.31	63.41

This sheep weighed at the beginning of the experiment 79¼ pounds, and at the end 80 pounds.

Sheep No. 3 received 7,938 grams of hay.

*Bul. 69, South Dakota Experiment Station.

**Table from Colorado Experiment Station Bulletin 135, p. 10.

	Dry Matter	Ash	Fat	Protein	Fibre	N-Free Extract
Hay	7648.66	1479.30	108.76	1635.20	1300.40	3125.00
Orts	2565.37	588.91	37.21	544.89	385.45	1008.89
Consumed	5083.29	890.39	71.55	1090.31	914.95	2116.11
Voided	2028.29	380.34	61.37	165.94	664.98	755.66
Digested	3055.00	501.05	10.18	924.37	249.97	1360.45
Coefficients of Digestion	60.10	57.28	14.23	84.78	27.29	64.29

This animal weighed at the beginning of the experiment 85.75, at the end 85.5 pounds.

PROXIMATE COMPOSITION OF AUSTRALIAN SALTBUSH HAY

Soluble in	Percent air-dried hay				
Eighty percent alcohol	30.107	Glucose	1.27*	Sucrose	0.45
Cold water	11.695	Gums	0.45		
Hot water and malt	4.452	Starch	0.52		
One percent hydrochloric acid	19.075	Xylan	4.77		
One percent sodic hydrate	15.482	Xylan	0.77		
Chlorin, etc.**	3.897				
Cellulose or residue	14.441				
	99.149				

*The reducing power of this decolorized extract is attributed to glucose and the increase effected by boiling with dilute sulfuric acid to sucrose.

**This consisted of treating the wet residue, after boiling with sodic hydrate, with chlorin for one hour, then boiling with sodic hydrate and finally with sulfurous acid.

EXPERIMENTS WITH SHEEP NO. 1

COEFFICIENTS OF DIGESTION FOR THESE EXTRACTS

	Total fed grams	Orts grams	Consumed grams	Voided grams	Digested grams	Coefficient grams
Eighty percent alcohol	2036.0	1392.7	643.3	172.2	471.1	73.23
Cold water	769.2	556.6	212.6	68.3	144.3	67.88
Hot water	292.8	317.2	-24.4	43.2	-706.	
One percent HCl	1254.6	721.7	532.9	321.7	211.2	39.63
One percent NaOH	1018.2	626.2	392.0	176.7	215.2	54.92
Chlorin	256.3	157.2	99.1	111.1	-12.0	
Cellulose	949.8	567.3	382.5	248.8	132.7	34.95
	6576.9	4338.9	2262.4	1142.0	1126.6	54.12

The orts gave a larger amount of hot water soluble than was contained in the fodder fed. This is the result obtained. We have no facts to give in explanation. The sheep, however, nosed the hay and rejected the leaves and to what extent it moistened these with saliva is unknown and how much difference such a fact might have made is also unknown. Notwithstanding the negative results given in the table, the coefficient of digestion calculated from these experiments for the dry matter of this hay is 49.50 against 49.19 found by using the whole hay and dung voided, so the results seem to be fairly reliable. With feces it has happened to us before that we have obtained negative digestibility due probably to the character of the fecal

matter. The preceding table considers the total extracts and does not attempt to divide them into any further components.

Sugars in Australian Saltbush Hay

The hay, however, contains some ready-formed sugars, gums, starch, hemicelluloses and cellulose proper. The gum, starch and celluloses can be converted wholly or partly into sugars that will reduce a Fehling's solution, i. e., throw down cuprous oxid. The compounds yielding these reducing sugars are unequally attacked by dilute hydrochloric acid and sodic hydrate. In some cases the hydrochloric acid extract shows a relatively large amount of reducing sugar, in others the sodic hydrate.

In the alcoholic extract after precipitation of coloring and other matters by lead acetate, sodic sulfate and copper sulfate, the solution is colorless unless an excess of copper sulfate has been added. The reducing power of this solution is attributed to the presence of glucose. This reducing power is increased on boiling with addition of sulfuric acid; this increase is attributed to the presence of sucrose because this would be the action of sucrose if it were present. The probability is that these sugars are actually present, but their quantity is small.

The reducing power of the inverted cold water extract is attributed to gums while that of the hot water and malt extract after deduction of the reducing power of the malt extract used is attributed to starch. None of these substances is present in the saltbush hay in any significant quantity.

The hydrochloric acid and sodic hydrate in succession attack the hemicelluloses with the production of reducing sugars. They presumably attack different groups and the sugars produced are proportional to their respective amounts present.

The treatment with chlorin, sodic hydrate, and sulfurous acid in succession had for its object the removal of lignones and the separation of comparatively pure cellulose. This extract showed no reducing action on Fehling's solution.

DIGESTIBILITY OF THE SUGARS IN THE EXTRACTS

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Glucose	83.53	52.95	30.58	none	30.58	100.00
Sucrose	138.18	85.47	52.71	6.51	46.20	87.65
Gums	29.59	25.16	4.43	4.23	0.20	45.14
Starch	34.20	10.44	23.76	none	23.76	100.00
Xylan (HCl)	313.72	195.25	118.47	90.78	27.69	23.37
Xylan (NaOH)	46.03	36.88	9.15	18.49	9.34	
Chlorin	None					
Cellulose	949.81	567.11	382.70	249.42	133.28	34.83

These sugars or carbohydrates, except the xylan, exist ready formed in the hay. Whether the sugar, here called xylan, split out by the sodic hydrate, is derived from the same parent substance in the fodder that yields this sugar on boiling with hydrochloric acid is not established. We have found but one case in the examination of six fodders in which there was any considerable quantity of this sugar, i. e., in corn fodder where the coefficient of digestion was found to be 28.20 percent. This does not mean that the digestion of the sugar proper was low but that the hemicellulose from which it was derived was in this case very resistant. The determination is probably correct and corresponds to an actual difference in the fodder. This is furthermore the only case in which boiling with 1 percent hydrochloric acid failed to remove practically the whole of this sugar or its corresponding hemicellulose.

The presence of fecal matter in the voidings that resists the hydrochloric acid but reacts with the sodic hydrate is indicated in the other cases. In the case of the corn fodder only is the amount of this xylan, formed by boiling the residue from the hydrochloric acid treatment with sodic hydrate, sufficient to show positively that any of it has been digested. Native hay gave a small amount but not large enough to justify considering it a positive result. In all cases except the corn fodder it appears that the whole of this xylan should be obtained in the 1 percent hydrochloric acid extract; in this respect the corn fodder differs from all the others.

Cellulose

The cellulose which in these analyses is comparatively pure, remaining after successive treatments with 1 percent hydrochloric acid, 1 percent sodic hydrate and then with chlorin gas and water with subsequent boiling with sodic hydrate and sulfurous acid shows a big variation in its coefficient of digestibility as is shown by the following arrangement of them.

Corn fodder	54.00 percent
Alfalfa	52.67 percent
Sorghum	47.44 percent
Timothy hay	41.61 percent
Australian Saltbush	34.83 percent
Native Saltbush *A. argentia*	28.97 percent
Native hay	16.47 percent

This cellulose is the crude fibre of our ordinary fodder analysis after it has been treated in the wet condition for one hour with chlorin gas and then boiled successively with sodic hydrate and sulfurous acid and its coefficient of digestion is different from that of the

technical crude fibre as ordinarily given. The coefficients for the crude fibre obtained for the samples of fodder just cited were as follows:

Corn fodder	56.71
Native Hay	55.56
Alfalfa	49.95
Sorghum	49.23
Timothy	36.08
Australian Saltbush	27.29
Native Saltbush	8.29

These results show that the cellulose is strongly acted on in the alimentary canal of the sheep but that the chlorin extract is scarcely attacked at all. This may be bad chemistry for the lignones removed by the chlorin treatment are closely related to the resulting woody fibre or cellulose. It would seem, however, that they resist the digestion of the sheep to a greater extent than the fibre or cellulose itself.

Furfural

There are carbohydrates in the fodders which on acid hydrolysis yield reducing sugars and under proper conditions the aldehyde known as furfural which can be made a measure of them. In the following table are the results obtained in trying to find to what extent these are digestible.

COEFFICIENTS OF DIGESTION FOUND FOR FURFURAL IN AUSTRALIAN SALTBUSH HAY AND ITS EXTRACTS.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Hay	602.5	320.3	282.3	122.9	159.3	56.45
Extracts						
Eighty percent alcohol	93.71	0.00	93.71	24.43	69.28	73.93
Cold Water	157.68	97.84	59.84	1.47	68.69	97.90
Hot water	30.32	20.00	10.32			
One percent hydrochloric acid	114.17	108.83	5.34	43.21	-37.87	
One percent sodic hydrate	129.24	51.03	78.21	51.03	27.18	53.26
Chlorin	28.87	19.05	9.82	6.80	3.02	30.57
Cellulose	49.26	26.68	22.58	26.68	-4.10	
			259.82	113.62	146.2	56.27

The coefficients for the furfural found for the different extracts vary and the feces, especially in the case of the hydrochloric acid extract yield more furfural than was contained in the fodder consumed, approximately eight times as much. We offer no explanation. The result for the orts is doubtful. The hydrochloric acid extract has in most cases, five out of seven including the present one, shown a medium coefficient of digestion, that of alfalfa a high one, 100

percent, while our native, the silvery saltbush, like the present one gave a negative result.

The coefficients found for some other fodders are given in the following table:

	Alfalfa Hay	Timothy Hay	Native Hay	Corn Fodder	Sorghum Fodder	Silvery Saltbush
Eighty percent alcohol	99.51	69.47	61.91	94.80	22.91	......
Cold water	100.00	71.07	6.79	100.00		88.99
Hot water and malt	67.44			100.00		
One percent hydrochloric acid	100.00	32.80	44.04	73.17	45.72	
One percent sodic hydrate	27.81	11.54	42.16	31.80	25.47	46.35
Chlorin		98.54		32.57	48.72	26.49
Cellulose	72.62	50.12	74.94			
Coefficients for whole hay	65.15	36.24	50.99	47.07	46.46	37.37

The sheep fed on alfalfa gained 9 pounds, on corn fodder 3.5 pounds, on native hay 3 pounds, on timothy no gain, on sorghum they lost 8.5 pounds and the same when fed the silvery saltbush, *Atriplex argentia*, but when fed Australian saltbush, *Atriplex semibaccata*, they held their own. The total difference found was .75 pound.

The Proteins

The coefficient of digestion of the proteins in this Australian saltbush hay, even with sheep No. 1 which did not take kindly to the fodder and made some trouble thru the feeding period, refusing to eat the leaves and behaving itself more or less badly, was high, 79.74 percent, and in the case of the other two sheep, it was 84.52 and 84.78 percent respectively.

COEFFICIENTS OF DIGESTION FOR THE PROTEINS IN THE RESPECTIVE EXTRACTS AS GIVEN BY SHEEP NO. 1

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Eighty percent alcohol	592.25	401.37	190.88	13.50	177.35	92.91
Cold water	49.92	45.09	4.83	18.41	-13.28	2.00
Hot water and malt	39.20	45.65	-5.89	......	2.00	2.00
One percent hydrochloric acid	219.75	116.87	102.88	......	102.80	100.00
One percent sodic hydrate	421.98	277.56	144.42	49.41	95.01	65.77
Residue	26.05	16.96	9.09	9.08	none	
			452.99		375.2	82.82

The nitrogen in the fodder that is soluble in 80 percent alcohol is highly digestible and that soluble in the 1 percent hydrochloric acid is even more so and the quantities extracted by these solvents are large. The quantity soluble in 1 percent sodic hydrate is larger than that soluble in hydrochloric acid and is also quite digestible but less so than the hydrochloric acid soluble.

The Urine

The protein (Nx6.25) found in the feces is assumed to be contained in undigested residues of the fodder and is usually only about 35 percent or less of that eaten. The amount voided in the urine becomes a measure of the use made by the animal of the protein digested, the extent to which it is changed and used up so far as the system is capable of using it. When the nitrogen compounds have reached this stage, they are eliminated. In the case of the native, silvery saltbush hay the animals consumed and digested almost as much protein (Nx6.25) as when they were fed on alfalfa hay; the proteins consumed in the former case were 1651 grams by the 3 sheep in 5 days; in the latter 1813, a difference of 162 grams. It happened that the same sheep were used in the two series of experiments so there was no allowance to be made for the individualities of the sheep. Those fed the saltbush digested 1095 grams of proteins, and those fed alfalfa, 1318 grams, a difference of 223 grams in favor of the alfalfa. While eating the saltbush, they drank a great deal of water and urinated freely. This was not examined nor even measured. The difference between the results of these two experiments was 17.5 pounds of flesh. Those fed on saltbush hay lost 8.5 pounds and those fed alfalfa gained 9 pounds. The sheep feeding on the saltbush hay did not appear to suffer any inconvenience but ate well and were contented. The only unusual features were excessive thirst and free urination. What produced the thirst and urination we do not know. The amount of ash constituents digested was larger in the case of the saltbush by 1524 grams than in the case of the alfalfa. What effect this may have had either in inciting the urination or in provoking thirst, I do not know.

The composition of the two ashes is quite similar. The coefficient of digestion is higher for that in the saltbush, 71.6 against 57.7 percent in the alfalfa. The principal difference in the composition is in the amount of carbonates in the prepared or carbonated ash. Potassium salts are very freshly taken up by the system, more largely so from the saltbush than from the alfalfa. These questions were not entered on beyond the analyses of the ash of the respective hays and dungs.

In the case of the Australian saltbush, we collected the urine and determined the amount of nitrogen eliminated during the period of the experiments. We shall multiply the amount found by 6.25 as tho we were dealing with proteins and this will, I think, serve our purpose. We fed a certain amount of nitrogen which we multiplied by 6.25 and of this a certain amount was taken up by the animal during 5 days. During the same time, it eliminates a given amount which we likewise multiply by 6.25 and the difference gives us the amount

changed in the animal's system. The animal itself is either gaining or losing weight and possibly doing neither, when we are just maintaining its condition. In this case the animal is building up out of the fodder eaten just as fast as the life processes are tearing them down. These processes are just in balance and the ration is a maintaining one for the time, at least, over which our observations extend. Our coefficients of digestion are based on such results.

These results are not adequate to answer the further question: Are the fodders sufficient to maintain the animal in normal health over a greater time without the aid of something else? We have called attention to the marked insufficiency of some fodders to maintain the weight of the sheep even for the short period of 5 days, i. e., the native saltbush and the sorghum, while timothy hay scarcely more than maintained the animals, but native hay, corn fodder and especially alfalfa hay enabled the animals to take on weight. The first pair of fodders constituted a veritable starvation diet; the second maintained the animals with a very slightly favorable margin; the third group was increasing the weight of the animals. We have suggested that the composition and coefficients of digestion were not adequate to explain these differences, but we did not examine the urine to see what was becoming of the nitrogen and the heat energy that was digested. We did determine the heat energy ingested and the amount taken up by the animal, i. e., digested, but made no attempt to determine how much was voided in the respiration and urine or otherwise escaped. We could not even attempt to ascertain this fraction but the animals were protected from the weather and wore good fleeces of wool so they were not unduly cooled by unfavorable weather conditions.

The urine voided by sheep No. 1 for which alone we have so far given our data voided during the 5 days the following quantities:

PROTEIN EQUIVALENT TO NITROGEN IN URINE OF SHEEP NO. 1 VOIDED IN 5 DAYS

	Grams Voided	Percent Nitrogen	Grams Protein
First	1023.0	1.335	83.50
Second day	718.5	1.512	67.95
Third day	1150.9	1.287	92.58
Fourth day	1269.3	1.180	94.00
Fifth day	1547.9	1.058	102.36
Total voided			440.29
Total digested			358.76
Excess voided			81.53

According to this there was a loss of proteins greater by about 81.53 grams than the amount taken up from the fodder consumed

or 358.76 grams. Our record shows that this sheep gained .25 pound. The total difference is essentially .5 pound. According to our weighings, the animal gained .25 pound but according to our analyses, it should have lost .25 pound. This is on the assumption that the loss and gain depended wholly upon the proteins digested and voided and that the nitrogen voided in the urine is exactly equivalent to the same nitrogen digested by the animal. These quantities, the nitrogen digested by the animal and that in the urine, are so nearly equal and the weight of the animal before and after the experiment is so nearly the same that the conclusion to be drawn is that we were simply maintaining the animal under the conditions of the experiment which were favorable. This was the result obtained in an earlier experiment with old sheep, i. e., they maintained their weight when fed green Australian saltbush for a period of 3 weeks and not for only 5 days as in this experiment.

The preceding statements are based upon the coefficients of digestion obtained experimentally and on the assumption that the proteins are important compounds in the fodder, which may not be correct. There are, however, other relations which we may adopt and which give us another measure, i. e., the heat produced when the fodder is completely burned, compared with that of the feces. We may even go farther and ascertain the value of the respective extracts of the hay and the feces and in this way ascertain how much energy the fodder yields to the animal's system. We can also ascertain the amount of heat or energy that escapes from the animal as urine. The amount lost from the body to the air and as water vapor we could not determine. Other experimenters have determined this not for our fodder, however, but for other fodders.

We have tried to work out our problem in this regard as far as we could and present the results.

We designated the ascertainment of the amount of soluble matter yielded to various solvents by the hay, orts and dung as a proximate analysis in Bulletin 124 and shall use the same designation here.

PROXIMATE ANALYSIS OF AUSTRALIAN SALTBUSH HAY, ORTS AND DUNG OF SHEEP NO. 1 FED ON IT.

	Hay	Orts	Dung
Soluble in 80% alcohol	30.958	32.098	15,081
Soluble in cold water	11.695	12.830	5.980
Soluble in hot water	4.452	7.310	3.780
Soluble in 1% hydrochloric acid	19.075	16.633	28.167
Soluble in 1% sodic hydrate	15.482	14.432	15.475
Soluble in chlorin, etc.	3.897	3,622	9.728
Cellulose	14.441	13.075	21.789
	100.000	100.000	100.000

HEAT VALUES OF ONE GRAM OF EXTRACT OF SALTBUSH, A. semibaccata, HAY, ORTS AND DUNG GIVEN IN SMALL CALORIES.

	Hay	Orts	Dung
Alcoholic extract	3404	3793	4753
Cold water extract	3839	2773	3193
Hot water, etc., extract		1846	3106
One percent hydrochloric acid	2809	2834	2914
One percent sodic hydrate	5079	4281	5039
Chlorin, etc., extract	5167	5083	6014
Cellulose	3876	3892	3986

Coefficients of digestion for the Heat Values

	Heat Units consumed	Heat Units voided	Heat Units appropriated	Coefficients
Whole Hay	10,082,149	4,621,674	5,460,470	54.15
Eighty percent alcohol	1,646,895	817,516	829,379	50.36
Cold water	1,352,170	217,124	1,135,046	83.97
Hot water	Negative*			
One percent hydrochloric acid	1,479,147	935,394	543,753	36.71
One percent sodic hydrate	4,053,809	891,933	3,161,906	78.00
Chlorin, etc.	526,277	667,544	-141,283	....
Cellulose	1,475,436	992,214	482,923	32.74

*This means that the orts contained more than the fodder fed.

The total urine voided by this animal in the 5 days of the experiment weighed 5706.9 grams. The heat value of this urine varied a little with the volume so we give the sum of the heat values found for the daily voidings which was 764,958 calories.

The heat appropriated by the animal from the whole hay was 5,460,470 calories. The urine voided was 764,958. This leaves 4,695,512 calories to be accounted for by the respiration and body losses of the animal, because there was no material gain in weight.

Heat Appropriated

The percentage of the total heat value appropriated by the animal, the coefficient of digestion, was, according to the results obtained by calculating this on the whole hay used, 54.15 percent. The amount indicated by the average of the positive results obtained with the different extracts of the fodder is 56.33 percent, as close an agreement as the method justifies us in expecting.

The results so far given were obtained with sheep No. 1, to which the fodder was not very acceptable, especially the leaves. Further, the animal showed signs of restlessness by butting the water container and otherwise. However seriously these facts may have modified our results, they are not bad; the animal actually gained a little flesh, not much, it is true, but enough to show positively that it did not lose in this time.

It should be kept in mind that our object is simply to ascertain whether this fodder is of sufficiently high quality to support animals for a reasonable period and not to ascertain its effect upon the growth and health of the animal if fed exclusively for a long period, when it might prove unable to maintain the normal health and functions of the animal. This is a question beyond our purpose and is a test in which many fodders considered good would fail to give favorable results. Only a few if any fodders when fed exclusively constitute a perfect ration.

In this connection, we recall the fact that the exigencies of the dry farmer are so pressing that sand grass and Russian Thistle are sometimes made into hay and the sorghum referred to in this and in Bulletin 135 was grown for this purpose.

RESULTS OBTAINED WITH SHEEP No. 2

Reference to page 10 will show that the coefficients of digestion of the whole fodder obtained in the case of sheep No. 2 and No. 3 are somewhat different from those obtained with sheep No. 1 and are higher thruout. That for the dry matter of the hay is 60.87, ash 62.00, fat 34.70, protein 84.52, crude 27.31, and nitrogen-free extract 63.41. The coefficients for fat and crude fibre are low tho they are higher than those obtained in the case of sheep No. 1. The portion designated crude fibre from different plants shows different coefficients of digestion and apparently is far more important than is usually indicated in the literature of feeding. The coefficient for the proteins is high in each of the three cases.

COEFFICIENTS OF DIGESTION FOUND FOR THE EXTRACTS.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Eighty percent alcohol	2457.5	660.8	1796.7	361.4	1435.3	79.8
Cold water	928.3	226.6	701.7	136.3	565.1	80.5
Hot water and malt	383.9	128.7	255.2	90.8	164.4	64.4
One percent hydrochloric acid	1514.2	429.0	1085.2	643.6	441.6	40.7
One percent sodic hydrate	1228.9	301.4	927.5	312.7	614.8	62.3
Chlorin	309.3	78.7	230.6	216.3	14.3	6.2
Cellulose	1146.4	298.3	848.1	517.5	330.6	37.8

The crude fibre usually given in a fodder analysis corresponds to the last two portions in this table. The results agree with the preceding one for this portion in showing that its digestibility is low and that the portion digested belongs to the cellulose proper and not to the lignones which we aimed to remove by treatment with chlorin and subsequently with sodic hydrate and sulfurous acid.

We have already explained the significance of sugars in these analyses; that they correspond to certain carbohydrates from which

they are derived. The only ready-formed sugars are the glucose and sucrose. The gums and starch exist in the fodder as such and are readily available carbohydrates. The portion designated as xylan means a form of sugar derived from the hemicelluloses by the action of hydrochloric acid and sodic hydrate used in succession. These results are probably not derived from the identical carbohydrates in different fodders. Most fodders, on being boiled with hydrochloric acid, yield the whole of this sugar that it is capable of yielding but not with equal readiness. A portion of the fodders resists the action of our solvents, even the most active ones, in the form of cellulose, a carbohydrate as well as the compounds from which the sugars given are derived, but this is not wholly indigestible tho it has resisted all solvents. It is the last residue.

Sugars Digested by Sheep No. 2.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Glucose	100.8	26.2	74.6	None	74.6	100.0
Sucrose	170.6	36.7	133.9	7.8	126.1	94.2
Gums	35.7	10.2	25.5	5.1	20.4	80.0
Starch	41.3	12.2	29.1	None	29.1	100.0
Xylan, hydrochloric acid	378.6	92.8	285.8	176.5	109.3	38.2
Xylan, sodic hydrate	55.6	16.1	39.5	32.0	7.5	19.0
Chlorin						
Cellulose	1146.3	299.0	847.3	538.7	308.6	36.4

Furfural Digested by Sheep No. 2.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Whole fodder	113.1	18.6	94.5	52.8	41.7	44.1
Soluble in:						
Alcohol	189.9	49.6	140.3	16.7	123.6	87.9
Cold water	36.6	Little	36.6	Little	36.6	100.0
Hot water	137.8	56.4	81.4	62.7	18.7	23.0
Hydrochloric acid	155.9	25.6	130.3	65.3	65.0	49.8
Sodic hydrate	34.8	6.6	28.2	18.8	9.4	33.3
Chlorin	59.5	19.9	39.6	30.1	9.5	24.0
Cellulose	727.6	176.7	550.9	246.4	304.5	55.3

Proteins in Extracts Digested by Sheep No. 2.

	Fed	Orts	Consumed	Voided	Digested	Coefficient
Whole fodder	1628.3	434.0	1194.3	186.2	1008.1	84.6
Soluble in:						
Alcohol	714.6	156.8	557.8	30.7	527.1	94.4
Cold water	60.3	24.1	36.2	18.2	18.0	49.7
Hot water	47.3	27.8	19.5	12.4	7.1	36.6
Hydrochloric acid	265.2	64.0	201.2	40.2	161.0	80.0
Sodic hydrate	509.3	147.9	361.1	62.3	298.8	82.7
Chlorin						
Cellulose	31.4	9.5	21.9	18.4	3.5	16.2
			1202.7		1020.5	84.9

The amount of proteins digested by the sheep in 5 days was 1020.5 grams. The sheep gained 340.2 grams during this time. The

ration was doing a little better than maintaining the animal. Supposing the gain of 340.2 grams to have been good edible mutton with 50 percent water and 15.5 percent protein in the dry matter, there would have been 26.4 grams of protein in it. The sheep digested 1020.5 grams of proteins and we here account for 26.4 grams, leaving 994.4 grams not accounted for. The urine contained nitrogen equivalent to 886.0 grams of proteins leaving a difference of 108.1 grams.

The statement is given in the following table.

Urine voided by Sheep No. 2 in 5 days.

	Volume in cc.	Sp. Gr.	Grams	Percent Protein	Protein
First day	2940	1,0359	3045.5	5.731	174.5
Second day	2930	1.0370	3038.5	4.688	142.7
Third day	3219	1.0340	3327.7	5.062	168.4
Fourth day	3730	1.0340	3856.8	5.790	223.3
Fifth day	3740	1.0340	3867.2	4.581	177.1
Total nitrogen voided calculated as protein					866.0

If our determinations are correct there was a small daily loss of nitrogen which was more than offset by gains of some sort, about four times more gain than nitrogen lost, but the loss was small and the final result was a slight gain in the weight of the animal.

Using the total hay fed, orts left and dung voided and determining the heat values, we find that the sheep actually appropriated 56.65 percent of it.

In the following table we have subtracted the value of the orts from that of the hay fed and given the difference under the caption of "consumed."

Heat units, small calories, taken up by Sheep No. 2 from the various extracts.

	Consumed	Voided	Digested	Coefficient
Whole Hay	21,095,910	9,144,800	11,951,110	56.6
Soluble in:				
Eighty percent alcohol	6,201,871	1,824,709	4,377,162	70.57
Cold water	2,774,043	337,479	2,436,564	87.81
Hot water and malt	439,310	191,043	248,267	56.51
One percent hydrochloric acid	3,135,414	1,720,986	1,414,428	45.11
One percent sodic hydrate	4,604,981	1,629,480	2,975,501	64.76
Chlorin, etc.	1,234,244	1,207,603	26,641	2.16
Cellulose	3,535,720	2,201,963	1,333,757	37.72

The coefficients are carried out to the second decimal place; this may seem a useless refinement but even so if the amount consumed be multiplied by the coefficient the product will not be exactly equal to the amount digested for every .001 percent added or rejected is equivalent to 10 units per million.

This table of heat units appropriated gives us a pretty clear idea of the relative values of the different extracts. The alcoholic ex-

tract of the Australian saltbush furnishes by far more heat than any other extract. The sodic hydrate, cold water and hydrochloric acid follow in order. The residual cellulose is only a little behind the hydrochloric acid extract in value but its coefficient of digestion is lower.

This animal voided a total of 17,135.7 grams of urine which had an average value or 88.9 calories per gram or a total of 1,523,364 calories. If we add to this the calories necessary to heat this urine to body temperature, we will account for 370,131 more calories. The further unaccounted-for losses are the heat of all other discharges and the cooling of the body.

The heat values of these extracts are very different and those of the dungs are different from the corresponding ones of the hay, but the preceding table gives the values as used by the animal, the result that we wish to present.

RESULTS OBTAINED WITH SHEEP NO. 3

Coefficients of Digestion found for the Extracts.
Extracts soluble in:

	Consumed	Voided	Digested	Coefficient
Eighty percent alcohol	1633.7	347.3	1286.4	78.7
Cold water	637.9	141.6	496.5	78.8
Hot water and malt	234.0	59.5	174.5	74.6
One percent hydrochloric acid	954.3	664.5	289.8	30.4
One percent sodic hydrate	840.0	280.0	560.0	66.7
Chlorin, etc.	218.8	190.8	28.0	12.8
Cellulose	791.3	446.9	344.4	43.5

Coefficients of Digestion found for the Sugars.

	Consumed	Voided	Digested	Coefficient
Glucose	71.9	0.0	71.9	100.0
Sucrose	119.6	8.5	111.1	92.8
Gums	21.9	9.0	12.9	58.9
Starch	37.3	0.0	37.3	100.0
Xylan, hydrochloric acid	206.6	163.8	96.8	37.1
Xylan, sodic hydrate	37.5	22.4	15.1	40.2
Chlorin, etc.				
Cellulose	792.1	447.1	345.0	43.6

Coefficients of Digestion found for Furfural.

	Consumed	Voided	Digested	Coefficient
Whole Hay	520.4	200.6	319.8	61.5
Extracts soluble in:				
Eighty percent alcohol	84.3	14.4	69.9	82.9
Cold water				
Hot water and malt	173.3	6.7	166.5	96.0
One percent hydrochloric acid	87.8	77.7	10.1	11.5
One percent sodic hydrate	109.1	58.5	50.1	46.4
Chlorin, etc.	25.0	18.8	6.2	24.8
Cellulose or residue	40.6	23.9	16.7	41.1
	520.0		320.0	61.5

Coefficients of Digestion for Proteins, found for Sheep No. 3.

	Consumed	Voided	Digested	Coefficient
Whole Hay	1082.6	168.4	914.2	84.4
Soluble in:				
Eighty percent Alcohol	486.8	36.3	450.5	92.7
Cold water	40.1	19.6	20.5	51.1
Hot water and malt	18.2	6.2	12.1	66.2
One percent hydrochloric acid	191.8	29.1	162.7	84.8
One percent sodic hydrate	327.3	60.8	266.5	81.4
Chlorin, etc.				
Cellulose	19.4	16.1	3.3	17.0
	1083.6		915.6	84.5

Proteins equivalent to Nitrogen Eliminated in Urine.

	cc voided	Sp. Gr.	Grams	Percent Proteins	Amount
First day	2055	1.044	2140.5	5.856	125.6
Second day	2310	1.047	2418.5	6.281	151.9
Third day	2360	1.046	2368.5	5.968	147.3
Fourth day	2740	1.042	2855.0	6.788	193.8
Fifth day	2620	1.043	2732.6	5.956	162.7
Proteins equivalent to nitrogen voided					781.3

The amount digested was 915.6 grams. We have a difference of 134.3 grams which in this statement would appear as gain, essentially .3 pound. The animal lost .25 pound. The temperature of the animal and the processes of life were maintained with this slight difference in the proteins concerned.

Heat units, small calories, taken up from the various extracts by Sheep No. 3.

	Consumed	Voided	Digested	Coefficient
Extracts soluble in:				
Whole Hay	19,199,736	8,376,961	10,822,775	56.4
Eighty percent alcohol	5,541,344	1,739,626	3,801,718	68.6
Cold water	2,699,223	474,502	2,224,721	82.4
Hot water and malt	301,700	97,432	204,268	85.2
One percent hydrochloric acid	2,834,601	1,821,394	1,013,207	35.7
One percent sodic hydrate	5,170,814	1,441,720	3,729,094	72.1
Chlorin, etc.	1,041,668	1,070,709	None	
Cellulose	3,154,425	1,856,997	1,297,428	41.1

The sheep voided a total of 12,615 grams of urine which had an average calorific value of 92.9 calories giving a total or 1,171,933 calories to which is to be added enough calories to heat 12,615 grams of urine from 15°C. which we may assume as the temperature of the water drunk, to the temperature at which it was voided, approximately 272,484 calories, the loss with other discharges and the cooling of the body.

Importance of Proteins

While it is evident that too much stress should not be placed on the so-called proteins (Nx6.25), it is customary to give these the first place in importance. It is convenient, at least, to exhibit the relations of these in our fodders, and we will choose that one which is accepted as our very best for comparisons. Of course all of our other fodders must fall below it in its general value but not necessarily in all of their constituents.

In Colorado Experiment Station Bulletin 128, 1907, we present alfalfa and one of our native saltbushes, *Atriplex argentia.* The alfalfa hay used in the experiments given carried 15 percent proteins and the saltbush 9.7 percent. Three sheep fed on alfalfa hay consumed 1817 grams of proteins and digested 1328 grams. The same sheep fed on native saltbush hay consumed 1646 grams and digested 1099. Of the 1328 grams proteins digested when fed alfalfa, 508 grams were soluble in 80 percent alcohol and cold water. Of 1099 grams digested when fed native saltbush hay, 553 grams were soluble in alcohol and cold water.

It may be stated in this connection that, owing to the small amount of extract obtained on treating a hay, alfalfa for instance, with cold water after previous extraction with 80 percent alcohol, a portion of alfalfa hay was extracted with cold water for 24 hours. In this time the water dissolved out, or better, the hay lost 40 percent of its weight. The inference was that cold water alone would remove practically as much from the hay as 80 percent alcohol and water used in succession. The hay treated in the course of our analysis, yielded in round figures 37 against 40 percent dissolved by the cold water in 24 hours.

In making alfalfa hay, it is a common practice to rake it into windrows as soon as it has wilted a little. This is done primarily to avoid loss of leaves and prevent breaking off more stems than can be avoided. Sometimes, however, changes in the weather bring about the wetting of the hay while it is in the swath, when a comparatively light rain will wash the hay badly and it does not require a heavy rain to wet it and injure it, even when it is bunched. The figure just given, 40 percent washed out of air-dried hay in 24 hours, suggests the possible extent of the damage.

The Hydrochloric Acid and Sodic Hydrate Extracts Persistent

The presentation of the relative value of these extracts shows that there is still a good deal of value left corresponding to the hydrochloric acid and sodic hydrate extracts which are less readily at-

tacked, but what the effects of fermentative action may be we do not know. It probably increases the action of moisture greatly. These are the three important portions of the hay.

The total amount of hay eaten was 12365 grams; of these 4482 were soluble in water or alcohol and water and 3611 grams were insoluble in alcohol and water, but soluble by successive treatments with 1 percent hydrochloric acid and 1 percent sodic hydrate. The portion soluble in alcohol and water (we actually used these two solvents but it seems from the result of our experiment that water alone would have dissolved as much) is roughly one-quarter more than that dissolved by the hydrochloric acid and sodic hydrate used in succession after the water extraction. This portion soluble in water is not only greater in quantity but has a higher coefficient of digestion. The proteins (Nx6.25) carried by the alcohol and water were 662 against 976 grams in the hydrochloric acid and sodic hydrate together. Their coefficient of digestion was about the same, not far from 80 percent.

Heat Units Removed by Successive Treatments

If we take the heat units removed from the hay, we have for alcohol and water 1550 calories per gram of hay and 1367 for the hydrochloric acid and sodic hydrate. Whichever way we choose to consider it, the alcoholic and aqueous extracts taken together constitute the most valuable portion of the hay and are equal to about 40 percent of its total value.

We have not studied the effects of rain on hays to any greater extent than herein indicated, except that we have analyzed alfalfa hay that had been damaged by rain. We have, however, studied the effects of rain upon the composition of the wheat plant quite extensively and found that the effects were very great.

The general impression of the damage done to alfalfa hay due to its getting wet, either in swath, windrow or cock is fully justified. The fact that the composition of the wheat plant, and with it the wheat or grain, is greatly affected by wet weather, justifies us in inferring that the alfalfa and other forage plants are susceptible to the same action.

This is an interesting subject and very important for our farmers. Wetting the ground in irrigating the crops produces an entirely different effect from drenching rains upon the plants even when standing and in a growing condition. When the plant is cut and lying in swath, it simply loses a big portion of its value. Alfalfa hay has

approximately one-half of its value washed out. Even wheat straw and also the grain give up a good deal to water.

The relation between the original value and these losses is given approximately by the extracts and their composition and thermal values.

I shall forego further suggestions that present themselves as of possible interest and state succinctly a few important facts in the way of a review.

BRIEF SUMMARY

We grew the Australian saltbush for eight successive seasons. It was planted on undesirable land for two seasons and grew satisfactorily. On better land, it produced plants 7 feet in diameter but much larger plants are mentioned in the California publications.

Its composition apparently varies with character of soil, both in its nitrogen content and in the amount and composition of its ash. The chlorin may be quite high or moderately low.

With us it had a good supply of water but it is asserted that it does well with only a small amount of water, 4.7 inches.

With us it is an annual but seeds itself freely. Its growth is prone but good yields of hay can be gathered. The plants were cut and cured with more care than could be given the hay on a large scale.

The plants were fed green to a horse and to three sheep. The animals all did well, apparently suffered no inconveniences or at most of a very temporary nature. The sheep maintained their weight for 3 weeks.

Digestion experiments were made also with three sheep, younger animals than the preceding ones. These also maintained their weight for the period of observation. The coefficients of digestion found are given in the preceding pages. There has been developed no objectionable features in it as a fodder; the one most seriously so is that none of the animals that we weighed made more than slight gains. All experiments were made under favorable conditions.

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SOME COLORADO TAX PROBLEMS

With Special Reference To Their Effect On Agriculture

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SOME COLORADO TAX PROBLEMS

Farm taxation studies in Colorado were proposed during the autumn of 1925. As a result of several conferences on this subject, the Division of Agricultural Finance, Bureau of Agricultural Economics, United States Department of Agriculture, and the Department of Economics and Sociology, under the direction of the Colorado Experiment Station, developed a plan for immediate consideration and began a cooperative study of taxation as related to the agricultural industry of Colorado.

This cooperative agreement became effective December 1, 1925. Our objective was to ascertain the present status of farm taxation in Colorado and the total burden of farm taxes for selected years; also to determine whether a revision of existing tax laws might not lead to a more equitable distribution of the tax load.

This bulletin includes a discussion of a part of the material which has been assembled as a result of the joint efforts of these two departments. It is hoped that this presentation may create a new interest in the study of public finance and that it may lead to constructive and intelligent effort in the improvement of present-day methods of securing and expending public revenue.

The immediate purpose of this bulletin is to supply to the farmers of Colorado information concerning the operation of their tax system. In order to furnish the necessary material for a general understanding and appraisal of the system, it has been thought necessary to lay chief emphasis on three subjects: (1) The relations between the income and taxation of various types of property; (2) the assessment of taxable property; and (3) an analysis of the receipts and expenditures of the various governmental units of the state. A brief explanation will show the interrelations of these three subjects.

The general property tax accounts for the bulk of the taxes collected from agriculture. For this reason the first two sections of this report will be concerned mainly with the general property tax. The third section will describe the receipts from all taxes and will show the amounts of taxes spent by the various governmental units.

A discussion of the burden of taxation is appropriate as the opening section of the report because of the wide interest in the subject of tax burdens, and because of the importance of the subject in any

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The authors desire to give due credit to Mrs. Thelma M. Penn and Mrs. Martha M. Adams for their careful work in making computations and in setting up many of the tables which have been used in this bulletin.

discussion of the effects of taxation. The chief data presented concern agriculture, altho an attempt is made to present comparable figures indicating the approximate tax burden of other industries and other types of property.

With an idea of the relative burdens of taxation in Colorado in mind, it becomes desirable to examine the reasons why taxes are at their present level. So far as the general property tax is concerned two factors determine the amount that an individual piece of property must pay: (1) Its assessed value, and (2) the tax rate. The second part of the report, therefore, proceeds to examine first the basis of the assessment system and the results of its operation, particularly in the rural sections of the state. Then the actual receipts of the state and local units are analyzed in order to show the amounts that have been collected by various means, particularly by the general property tax. Finally the expenditures of the various units are examined with especial attention being given to those that relate to agriculture and to those of the local units that are primarily agricultural.

On the basis of the examination of tax burdens in the state, of the assessment process by which these burdens are distributed over the various types of property, and of the actual tax receipts and expenditures, a tentative appraisal of the tax system of the state so far as it relates to agriculture is reached. The analysis indicates certain methods by which an improved system may be obtained. It also points the way to several additional lines of research that need attention before anything that approaches a final appraisal of the state's tax system can be made.

I. INCOME AND TAXATION OF COLORADO FARMS

Income is generally considered the best single test of ability to pay taxes. From income must come tax payments unless capital is to be levied on and diminished. A comparison, therefore, of the amount of income taken by taxes levied in various years and on various types of property gives much information that will help to determine the effects and fairness of a tax system. In this chapter, the results of studies of farm income and taxation made in Colorado will be described and compared with results of similar studies in other states. They will also be compared with the figures that are available relating to the taxation of types of property other than agricultural. From the material that can be gathered, an estimate of the relative burden of taxation in Colorado will be prepared.

Data concerning farm income and taxes have been secured from two sources. Questionnaires have been sent to owners of rented farm land in the state, requesting that they supply certain information

relating to the years 1919, 1923, 1925 and 1926. From these questionnaires data which concern the state as a whole have been computed. In order to have more detailed information for certain important agricultural areas, detailed field investigations have been made, and based on them it is possible to present an intensive picture of conditions in certain sections.

It will be noted that major emphasis is placed on the results of the studies of returns on rented land. It is possible definitely to compute the income that is properly attributable to land of this type. Such a computation cannot be made without certain arbitrary assumptions for land that is farmed by its owner. Income reported for such land includes return on the operator's investment, and on his labor and his managerial ability, and it has been impossible satisfactorily to separate these types of income. In other words, the first portion of this farm-income and taxation study will be concerned with property income and a latter portion with personal income and property income combined. Rent in the first portion of the study will be used as a basis of the income figure, with which taxes on land and buildings will be compared. The rent figure reported on the questionnaires has been changed to a net rent figure by the deduction of insurance,[1] depreciation on buildings and fences,[2] cost of seed and other supplies furnished by the landlord, interest on the landlord's investment in livestock and machinery, and certain other deductions which appear fair in special cases.

A comparison of the results of the questionnaires, which cover the years 1919, 1923, 1925 and 1926, and which are summarized in Table 1, shows that taxes took the greatest percentage of net rent—computed without deducting taxes—in 1923, when the average for 414 farms was 37.8 percent. In 1925, reports from 568 farms showed that net rent [3] had increased slightly and that taxes had decreased. Taxes in that year amounted to 33.2 percent of net rent. The following year brought a slight additional improvement in farm owners' tax position. Reports from 304 farms indicate that taxes took 32.6 percent of net rent. These recent years should be compared with 1919, when reports from 282 farms indicate that taxes were 22.7 percent of net rent. Figure 1 presents this comparison in graphic form. It will be noticed that the improvement in the condition of the land owner in the two recent years has been due to a decrease in the tax per acre rather than to any increase in the income from land.

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1 Computed at 50 cents on a $100 valuation of buildings, the current rate for mutual farm fire insurance as computed by the U. S. Dept. of Agriculture.

2 Computed at 3 percent and 8 percent, respectively.

3 Net rent, when used in the following pages, should be understood as meaning net rent before deducting taxes.

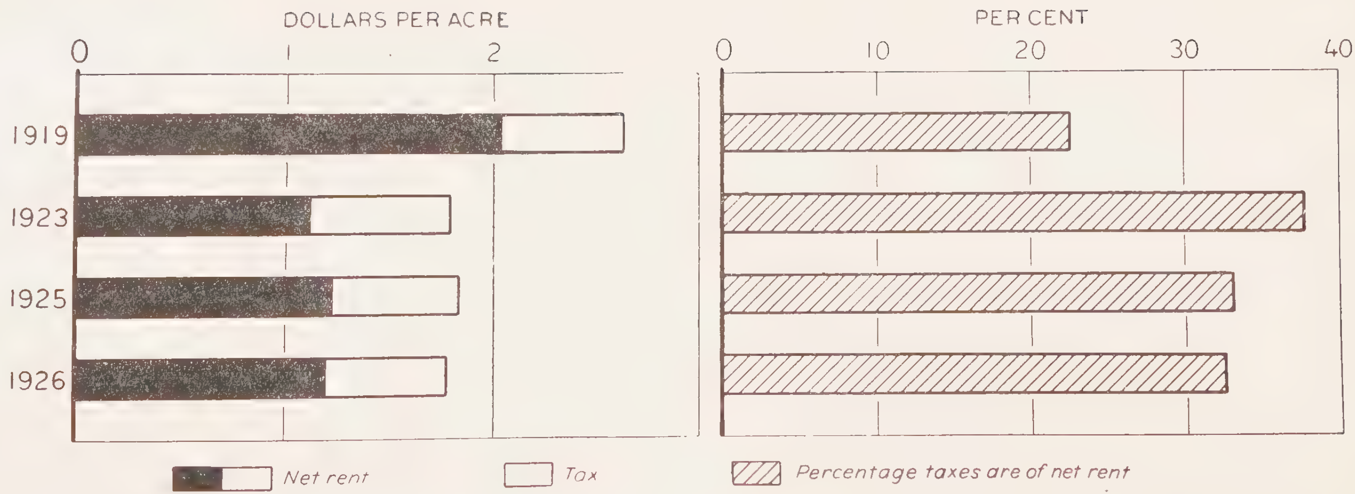

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Figure 1.—Relation of Taxes and Rent on Farms in Colorado, 1919, 1923, 1925, and 1926. Net rent was highest in 1919, lowest in 1923 and close to the 1923 level in 1925 and 1926. Taxes were highest in 1923, making the percentage of rent taken by taxes highest in that year.

TABLE 1.—General Property Taxes and Net Rent of Farms Reporting in Colorado, 1919, 1923, 1925 and 1926.

Year	Farms reporting	Acres in farms reporting	Average size of farms	Net rent per acre (before deducting taxes)	Tax per acre	Relation of taxes to net rents
	Number	Acres	Acres	Dollars	Dollars	Percent
1919	282	88,832	315	2.64	0.60	22.7
1923	414	127,829	309	1.80	.68	37.8
1925	568	182,185	321	1.84	.61	33.2
1926	304	98,199	323	1.78	.58	32.6

Average figures for a state the size of Colorado frequently fail to reveal conditions that affect only a portion of the state. In order to make the figures presented of greater local significance, they have been tabulated in groups of counties which comprise certain of the agricultural regions of Colorado and the results included in Table A.[1] A further tabulation on the basis of individual counties would have been made if a sufficent number of returns had been secured. It is not believed, however, that the returns available are sufficient to represent properly all types of agriculture within many of the counties. Figures for certain districts into which intensive studies have been carried are on pages 17-18, infra. Within the districts[2], indicated in Figure 2 and designated as Northern Colorado, the Plains, the Arkansas Valley, Southeastern Colorado and the Western Slope, it is believed that an adequate sample to indicate general trends of rent and taxation has been secured. Figure 3 compares taxes and net rents for the four years for which information is available in each of the five regions. It is to be expected that the average amounts of rent and taxes per acre will vary in the different sections. For purposes of comparison the relationship between net rent and taxes is of more significance than the figures for either taken alone. Is a greater proportion of the net income from land taken by taxation in one section of the state than in another?

The answer to this question should indicate whether there are local conditions which need special study in order to bring tax equality among the different sections. This problem may be fully as important as a consideration of such inequalities as may exist between agriculture and other industries.

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[1]In order to make the reading of the report more easy for those who do not wish to examine all the tables, certain of the less important ones have been placed at the end. These are designated by letters. Table A appears on page 81.

[2]The counties from which reports have been received in each of the districts follow: Northern Colorado—Adams, Boulder, Larimer, Logan, Morgan, Sedgwick and Weld; Plains—Arapahoe, Cheyenne, Elbert, El Paso, Kiowa, Kit Carson, Lincoln, Phillips, Washington and Yuma; Western Slope—Delta, Mesa and Montrose; Arkansas Valley—Bent, Crowley, Otero, Prowers and Pueblo; Southern Colorado—Baca, Huerfano and Las Animas.

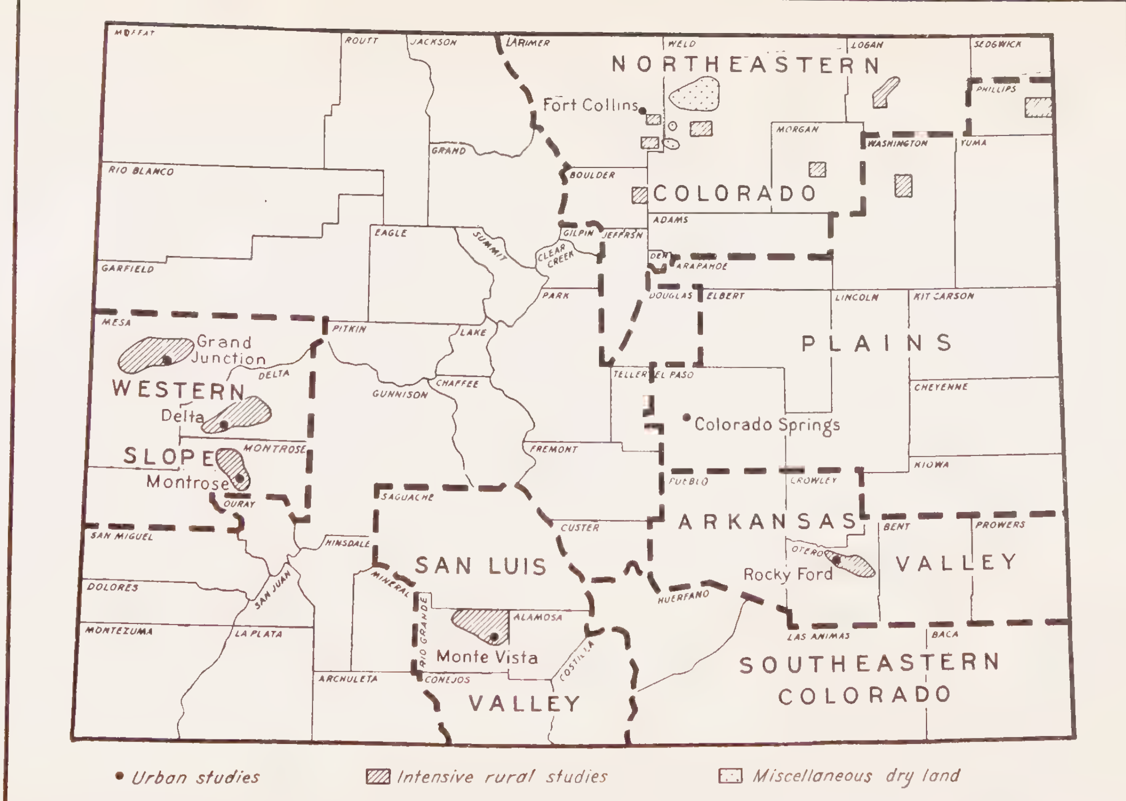

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Figure 2.—Counties, Cities, and Districts Forming the Basis of the Regional Comparisons of Farm and Urban Rents and Taxes.

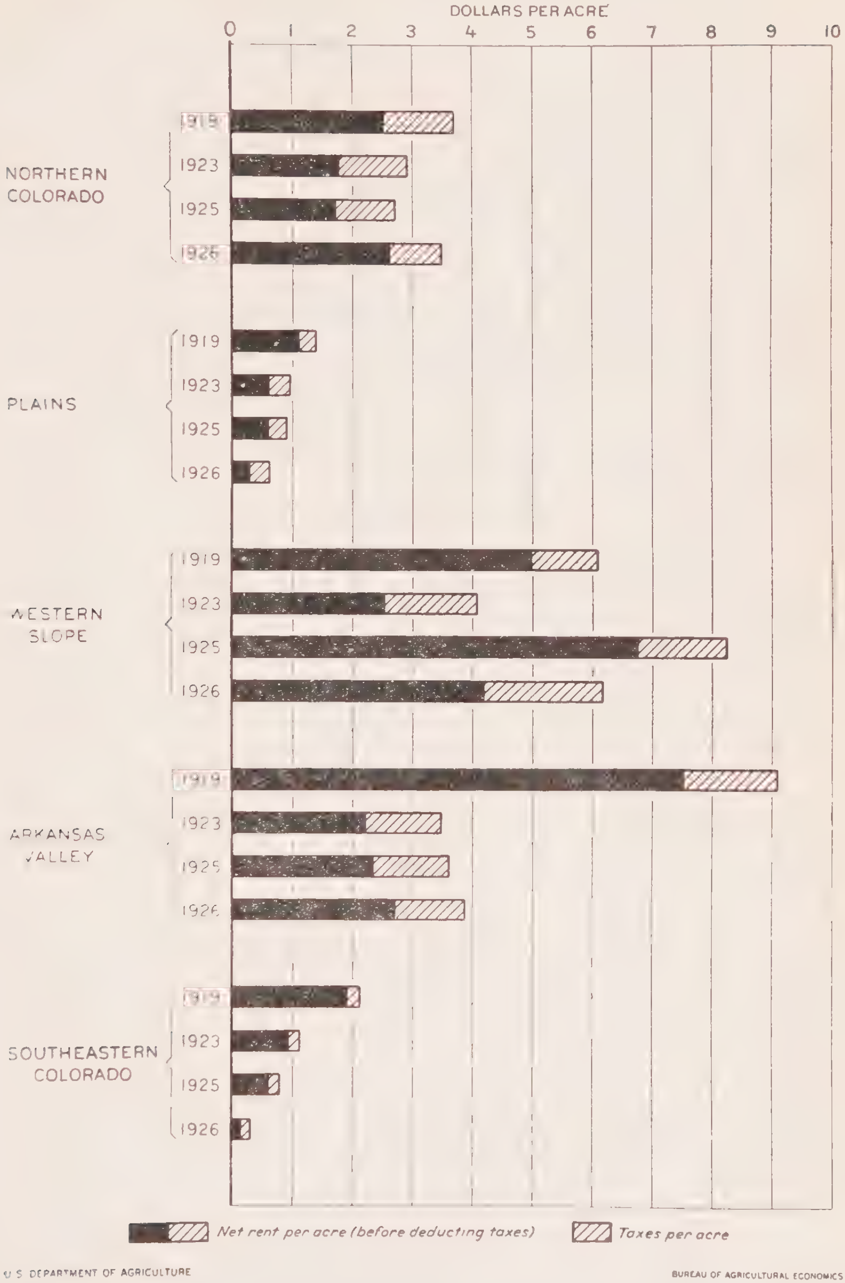

Figure 3.—Relation of Taxes and Net Rent on Farms in Several Districts of Colorado, 1919, 1923, 1925, and 1926. The Arkansas Valley in 1919 reports the highest net-rent per-acre figures, closely followed by the Western slope in 1925. Per-acre rents are consistently lowest in the Plains and Southeastern Colorado.

In 1919 the farms of the Plains, Southeastern Colorado, the Western Slope and the Arkansas Valley were in a better tax position as revealed by the percentage of net rent taken by taxes than farms in Northern Colorado. A condition of general uniformity for all the regions, except Southeastern Colorado which again was in a better condition than the others, is revealed by the results for 1923. In 1925 the Western Slope and Southeastern Colorado show a distinctly better ratio than the other sections. In the following year Northern Colorado, the Arkansas Valley and the Western Slope, are in a more favorable tax condition than the other regions. While this review shows that the farms which reported from the Western Slope and from Southeastern Colorado have paid a lower portion of their income in taxes than have those of the remaining sections from which reports have been received, the small number of farms which have reported from these two sections makes some caution necessary in drawing conclusions from the figures.

In the Plains and Northern Colorado sections where the number of reports is adequate to present a fair sample, an important difference is indicated. The ratio of taxes to net rent in Northern Colorado was high in the two early years covered by the study and relatively low in 1926. In the Plains section, the ratio was below the average for the state in 1919 and 1923. For the last two years covered by the study, it was above the average for the state, running materially above it in 1926.

It is of interest to trace the reasons for the change in ratios in each of these cases. Net rent in Northern Colorado, as in the rest of the state, was at its peak in 1919. It declined in the two following years for which figures are available, but in 1926 it increased until it approached its peak of 1919.

Taxes, on the other hand, declined in each of the years which were studied since 1919. Net rent per acre was also at its high point in the Plains region in 1919. It declined in each of the years covered since then, and in 1926 was less than half of the 1919 figure. Taxes on the Plains farms increased from 1919 to 1923, dropped off slightly in 1925, and the following year increased almost to the 1923 level.

While there are pronounced differences among the farming sections of Colorado in the tax situation of land owners, there seems to be no single section which in each of the four years covered has been greatly worse than the other sections. It is not possible from the data presented to say that any section or sections need relief to the exclusion of the rest. If similar data could be presented for counties, it is believed that certain of them would be found in which the tax-

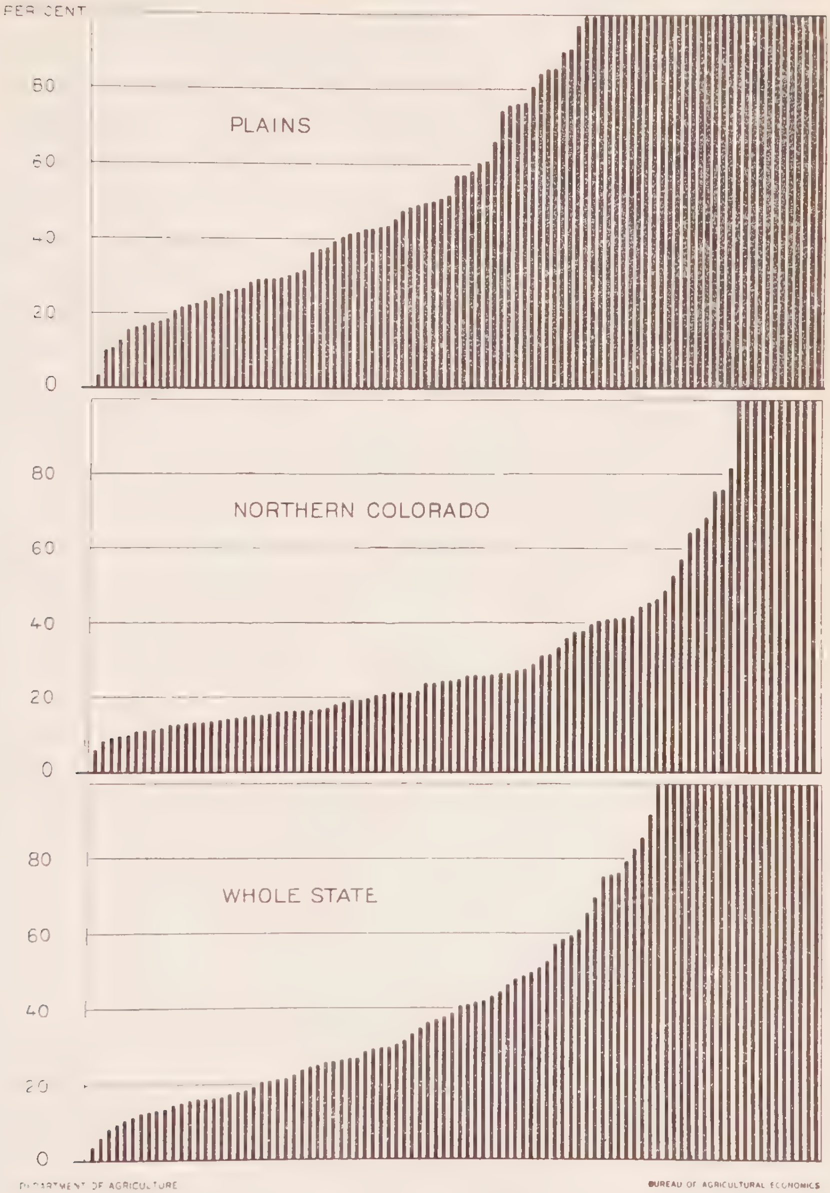

Figure 4.—Percentage of Property Earnings Taken by Taxes of Individual Rented Farms, Colorado as a Whole, Northern Colorado, and the Plains, 1926. Each bar in the Plains and Northern Colorado sections of the chart represents a single farm. Each one in the whole-state section represents three farms. Only farms reporting some income before paying taxes are included in the chart. This involved the omission of 3 farms in Northern Colorado, 17 in the Plains, and 30 for the whole state as these farms reported a deficit before taxes.

payers have a more difficult time financing the necessities of government than in others.

As has already been mentioned, the statistical data relating to incomes and taxes are not sufficiently numerous in more than a few scattered counties to make their presentation on a county basis feasible. One fact relating to inequality is indicated by the figures that have been gathered. In those counties where income is extremely variable, the relationship between taxes and income will also tend to fluctuate sharply. In other words, taxes are a relatively fixed charge. For any particular year they are determined without reference to that year's income. They have little direct relation to income in any year. This fact is most clearly appreciated in those years and regions where a drouth or other disaster has seriously affected agricultural income. In a state the size of Colorado, where conditions may vary greatly from one section to another, some equalization to take account of such conditions should be possible. This subject will be reverted to later, after more data on the subject of inequalities have been presented.

It has been shown that certain variations in the ratio of taxes to rent exist between sections. Within any one section, however, the variations between individuals are far more striking than are the average variations between sections. The data from each farm reporting in 1926 have been tabulated and the relation between taxes and income for each computed. Figure 4 shows this relationship for the 304 farms reporting. It will be seen that for half of these, farms taxes took 45 percent or less of net rent. Over a quarter paid 25 percent or less of their net rent in taxes. Not quite three-fourths of the farms are included among those on which taxes took 100 percent or less of the net rent which was left before deducting taxes. In other words, over one-quarter of the farms reporting in 1926 suffered a deficit after paying taxes. Thirty of the farms, or 10 percent of the total number reporting, had failed to yield enough to pay deductions from gross income other than taxes.

Figure 4 also contains a similar comparison for the farms of Northern Colorado and for those of the Plains. In the latter region it has been pointed out that the ratio between taxes and rent was particularly unfavorable in 1926. Seventeen of the 113 farms reporting had deficits before paying taxes, and half paid 80 percent or more of their net rent in taxes. Less than 40 percent had half their net rent left after paying taxes. In Northern Colorado, where conditions were reasonably good in 1926, half the farms paid less than 25 percent of their net rent in taxes. Only three farms reported a deficit before paying taxes, and less than one-quarter of the farms reported paying more than half their net rents in taxes. In making

this comparison between the two sections, it must constantly be kept in mind that the situation on the farms reporting in the Plains section was particularly bad in 1926 and that the differences are more extreme than they would have been in the other years. Conditions in the two sections do furnish a striking example of the effects of a relatively inflexible tax system on farms that are subject to years of exceedingly low income.

PROFITS AND TAXES ON OWNER OPERATED FARMS

In addition to the data that have been presented for rented farm property it seems desirable to consider briefly the situation of the farmer who owns and operates his farm. It must be kept firmly in mind in this discussion that the profits figure discussed is not equivalent to the net rent figure that has been used in the preceding pages. Net rent represents property income. Profits, as here used, represent the income from farm property, plus income due the operator for his managerial labor, i. e., all return for his personal efforts save a labor allowance computed at the rate paid hired labor.

Such figures appear in Table 2 and were secured in the Rocky Ford area of the Arkansas Valley, the Monte Vista area of the San Luis Valley, the Montrose, Delta and Grand Junction areas of the Western Slope and the Greeley area of Northeastern Colorado for the year 1926. Records for the year 1922 were secured in the Rocky Ford and Greeley areas.

Farm receipts as considered in the data summarized in Table 2 comprise receipts from crop and livestock sales, increase in inventory and appreciation on real estate, livestock, equipment and supplies. Farm expenses comprise current expenses, depreciation on equipment, livestock and real estate, interest on investment in equipment and livestock and interest on cash to run farm, decrease in inventory, and a fixed charge for operator's labor. Farm profits rep-

TABLE 2.—Profits and Taxes on Owner-operated Farms in Several Districts of Colorado, 1922 and 1926.

District	Number of records	Profits before deducting taxes	Taxes	Taxes as a percentage of profits before deducting taxes
		1922		
Arkansas Valley	13	$ –1,040.00	$ 3,453.00	....
Northeastern Colorado	21	13,710.23	9,182.51	67.0
All districts	34	12,670.23	12,635.51	99.7
		1926		
Arkansas Valley	10	$ 17,690.00	$ 2,076.00	11.7
Northeastern Colorado	18	87,843.26	8,368.09	9.5
San Luis Valley	23	212,290.00	14,065.00	6.6
Western Slope	30	24,551.90	5,201.20	21.2
All Districts	81	342,375.16	29,710.29	8.7

resent the difference between receipts and expenses, and include, besides the return from the real estate before deducting interest on investment in real estate and operator's wages of management.

In 1926 taxes took an average of 3.64 percent of total farm receipts. They represented 5.9 percent of farm expenses and 8.7 percent of farm profits on the 81 farms studied. The average percentage of farm profits consumed by taxes was highest in the Western Slope district, 21.2 percent. It was the lowest in the San Luis Valley district, 6.6 percent. Taxes took the greatest share of the receipts in the Arkansas Valley district and constituted the largest share of the expenses in the San Luis Valley. The high percentage of taxes to farm profits in the Western Slope district was evidently due to low income rather than higher taxes.

When taxes, as a percentage of farm receipts, expenses and profits in 1922, are compared with these items for 1926, it is found that taxes consumed a much larger share in 1922 than in 1926. Much of the difference shown between 1922 and 1926 was due to low receipts in 1922 rather than to higher taxes in that year. While the taxes were higher in 1922 than in 1926, they were not so high as to make the difference indicated.

INCOME AND TAXATION OF URBAN PROPERTY

Figures have been collected for rented urban property in the cities of Colorado Springs, Fort Collins, Rocky Ford, Monte Vista, Montrose, Delta and Grand Junction. While such figures can not be put forward as definitely representative of all urban conditions of the state, outside of Denver, it will be seen from the map on page 12 that these cities are located in different sections and so present a fairly adequate idea of the burden of taxation on urban property in rather widely separated parts of the state. A statement of total rent received on each of the 154 urban properties has been secured from its owner or his agent. The various expenses deductible from gross rent have also been recorded. Tax figures have been taken from the county records. The computations have been kept as closely comparable as possible to those used to arrive at the income and taxes of rural property. The figures are summarized in Table 3.

Total taxes including city taxes on 94 business properties accounted for an average of 27.4 percent of the net rent received from these properties. Taxes on 60 residence properties consumed 34.3 percent of the net rent derived from them.

Taxes on business properties expressed as percentages of net rent are highest in Delta, 42.5 percent, and lowest in Fort Collins, 22.6 percent. Taxes on residence properties expressed as percentages of net rent are highest in Rocky Ford in the Arkansas Valley

district, 52.0 percent, and lowest in Monte Vista in the San Luis Valley district, 29.1 percent.

It is instructive to compare taxes as percentages of net rent in Colorado Springs, one of the largest cities of the state, with the percentage obtaining in the six other towns included in the survey, namely, Fort Collins in the Northern Colorado district, Rocky Ford in the Arkansas Valley district, Monte Vista in the San Luis Valley district, and Montrose, Delta and Grand Junction in the Western Slope district. It is found that the average tax as a percentage of net rent on business properties is higher in Colorado Springs than the average for the business properties of the other six towns. The average tax expressed as a percentage of the net rent on residence properties is lower in Colorado Springs than the unweighted average for the other six towns.

Urban taxes other than city taxes i. e., state, county, and school district taxes, in comparison to net rents received from these properties, were found to vary from 6.7 to 50.6 percent in 1926. Business properties varied from 6.7 to 50.6 percent while residence properties showed a variation from 8.2 to 44.5 percent. The average for business properties was 18.1 percent; for residence properties, 21.9 percent. Altho greater variation is found among the business preperties, the average is higher among the residence properties.

TABLE 3.—General Property Taxes and Net Rent of Urban Property in Seven Cities of Colorado, 1926.

Cities	Number of records	Net rent before deducting taxes	General property taxes	Taxes as a percent of net rent before deducting taxes
Business properties:				
Colorado Springs	15	$ 85,767.00	$ 25,114.66	29.3
Delta	11	15,091.00	6,408.06	42.4
Fort Collins	29	125,942.00	28,453.90	22.6
Grand Junction	10	41,607.00	12,619.75	30.3
Monte Vista	12	20,539.00	4,728.59	23.0
Montrose	3	7,941.00	1,958.06	24.7
Rocky Ford	14	18,426.00	7,278.73	39.5
All Cities	94	315,313.00	86,561.75	27.4
Residence properties:				
Colorado Springs	19	$ 4,648.00	$ 1,451.69	31.2
Fort Collins	9	2,394.00	725.84	30.3
Grand Junction	7	1,977.00	648.82	32.8
Monte Vista	9	2,690.00	783.92	29.1
Montrose	2	433.00	177.65	41.0
Rocky Ford	14	2,164.00	1,124.52	52.0
All Cities	60	14,306.00	4,912.44	34.3

Considering Montrose, Delta and Grand Junction as representative of the Western Slope district, Monte Vista of the San Luis Valley district, Rocky Ford of the Arkansas Valley and Fort Collins of northeastern Colorado, a comparison of taxes other than city in these districts among themselves and with Colorado Springs, one of the larger cities of the State, not agricultural, may be enlightening.

Among the cities of the agricultural districts the Western Slope shows the highest percentage of taxes other than city in comparison to net rent, 21.9 percent. Northeastern Colorado shows the lowest percentage, 15.1 percent. Of the business properties, the Western Slope has the highest percentage of taxes other than city in comparison with net rent, 21.9 percent. The highest percentage of taxes among residence properties was found in the Arkansas Valley. Northeastern Colorado exhibits the lowest percentage in both business and residence properties, 15.0 and 19.5 percent respectively.

Comparing the towns in the agricultural districts with Colorado Springs, it is found that the average percentage for Colorado Springs is slightly higher among business properties and slightly lower among the residence districts.

It is of some value to compare general property taxes expressed as a percentage of rural net rent with general property taxes expressed as a percentage of urban net rent. The figures presented in Table 4 represent a by no means exhaustive study of the tax-and-income situation in country as compared with the city but are suggestive and altho the number of records is limited, are considered to be fairly representative of the districts covered.

TABLE 4.—Comparison of the Percentages of Net Rent Taken by Rural and Urban Taxes, 1926.

District	Rural Properties[1]		Urban Properties[2]		
	Properties reported	Percentage of net rent taken by taxes	Properties reported	Percentage of net rent taken by total urban taxes	Percentage of net rent taken by urban taxes other than city
	Number	Percent	Number	Percent	Percent
Northern Colorado	100	21.9	38	22.7	15.1
Western Slope	27	32.0	33	32.5	21.9
Arkansas Valley	45	28.0	28	40.8	21.2
San Luis Valley	27	12.4	21	23.7	17.0
Total	180	23.8	120	27.1	17.7

[1]The difference between the figures for rural properties in Table 4 and Table A arise from the fact that comparable figures from two separate surveys are combined in order to give a more representative sample in Table 4 than could be obtained from the figures of Table A alone.

[2]The figures for urban properties are computed on the basis of a simple summation of business and residence figures. The fact that the rent of business properties amounts to much more than that of the residence properties gives the former much greater weight in the combined figure. If the two types of property are given equal weight the percentages will be slightly increased, but the change is not sufficient to alter the conclusions of the text.

Total taxes expressed as a percentage of urban net rent are greater than total taxes expressed as a percentage of rural net rent; 27.1 percent as compared with 23.8 percent. In each of the four districts studied, total taxes consumed a larger share of net rent on urban properties than on rural properties.

If, however, one is to compare taxes other than city taxes, i. e., state, county, and school-district taxes on the urban properties with these same taxes on rural property, it is found that taxes take a greater part of net rent on rural property than on urban property; 23.8 percent compared with 17.7 percent. In only one district, the San Luis Valley district, is the tax on rural property less in comparison to net rent, than taxes other than city or urban property; 12.4 percent as compared with 17.0. The significance of such a comparison lies in the fact that the city taxes are, in the main, a charge for services which are rendered to the city taxpayer but which are in no sense duplicated in the rural sections.

Comparisons with Other States

It is reasonable to ask whether the Colorado farmer is in a worse situation, so far as taxes are concerned, than is the farmer in other states. It is unfortunate that there is little recent information from nearby states on the subject. Data have, however, been collected from owners of rented farms in some few states and the results of such studies are comparable with the one that has been made in Colorado.

It was found that the owners of rented farms in certain sections of Michigan paid in taxes 55 percent of their net return in 1926, while for the eight years from 1919 to 1926 they paid 52 percent. On farms in three counties of North Dakota, taxes were found to take 16 percent of the net rent in 1924 and about 40 percent over a period from 1919 to 1924. In South Dakota certain rented farms paid 30 percent of the net return to their owners in taxes in 1926 and 28 percent over the period 1920-1926. A study of rent and taxes on nearly 1,100 farms in Virginia indicated that in 1926 taxes took 20 percent of the net returns to the farm owners. Reports from Arkansas showed that taxes took 17 percent of the net rent of farms in five representative districts in 1925 and averaged 18 percent over the five-year period 1921-1925. In three counties of Indiana, taxes on rented farm land, from 1919 to 1923, averaged 33 percent of the net income and in the year 1923, averaged nearly 40 percent. A report from Missouri shows taxes on farms in four counties to have taken 16 percent of net rent over the same five-year period and 20 percent in the year 1923. Figures from certain selected farms in Ohio indi-

cated that about 36 percent of the net rent went into taxes during the years 1919 to 1922.

The only conclusions that can be drawn from the figures that have been presented from other studies are that farm taxes wherever they have been studied are taking a heavy toll from the land owner's income and that the situation in Colorado is about the average – not as unfavorable as in the states where taxes are heaviest when compared with income, but somewhat worse than in a few states where the tax situation seems most favorable. In this connection, one particular qualification needs to be kept in mind. Taxes should be measured in two ways—by the amount that the taxpayer is compelled to pay and by the things which he receives as a result of such payment.

Thus, two groups of farmers may each be paying out the same proportion of their net incomes in taxes and still their real tax burdens may be very different. In one community tax money may be spent efficiently, governmental organization may be adapted to the needs of the locality, and excellent roads and schools may be provided. In another, inefficiency, not necessarily blamable to any individuals, but possibly inherent in the governmental organization, makes it necessary to exact a high proportion of income in taxes and still does not permit the maintenance of satisfactory roads, schools and other governmental services. It requires no argument to prove that if the farmers of the two communities are paying the same proportions of net income in taxes, those of the latter community have a much heavier tax burden than those of the first. For these reasons the comparisons that are made between taxes and incomes among different communities and to some extent, among different groups, need to be considered as a starting point for a study of tax burdens, rather than as a definite indication of the amounts of the burdens.

In so far as the ratio between the net income of rented farm land and taxes on that land are concerned, there will tend to be, over a period of years, an adjustment in net rent which will somewhat reflect the value of the services rendered to the land and to those who live on it by the governmental agencies. Thus, a farm that is located near good roads and schools will be expected over a period of years to rent for more money than a farm similar in other ways, but not convenient to good roads and schools. Such adjustments, however, particularly in the case of schools, are apt to be made only after a long period of years, and with the lack of stability in income from land which is characteristic of present conditions, may never become apparent. For the reasons that have been mentioned, however, the ratio between net rent and taxes needs to be considered subject to an adjustment based on the governmental services in return for taxes paid.

INCOME AND TAXATION OF COLORADO PUBLIC UTILITIES

Taxation of public utilities, particularly during the past few years, has been high. It may be urged as an attenuating factor that the rates of those public utilities which have their charges fixed by the state are intended to permit such utilities to make a fair return on their value. If such intentions work out in practice the utilities will be able to pass on to their customers the taxes which they pay. It is a well-known fact that in recent years certain types of utilities have made little or no profits. With fairly high taxes it can be understood that the percentage of operating profits, before deducting taxes, which is taken by taxation, will be high. It is not, however, wholly fair to compare such percentage with the percentage of farm income or of income from farm land taken by taxes. Farm taxes as a whole cannot be shifted. Figures presented for income from farm land are investment-income figures and should only be compared with other figures considered on that basis. The qualifications that must be kept in mind in any use that is made of the farm-business-income figures have already been explained.

In spite of the reservations that have been made in their use, it has been deemed of sufficient interest to present, in Table B[1], public-utility-income figures for the years 1922 and 1923, the latest that have been published by the Public Utilities Commission of Colorado. The percentage that taxes take of net operating profits varies among the different types of utilities, the highest figure recorded being 54.2 percent in 1923 for gas companies. This figure, however, should be considered with the electric light and power company figure for the same year as it seems probable that arbitrary assignment of income to either gas or electricity was made by certain of the companies which supply both utilities. If gas and electricity are combined it is found that taxes took 25.0 percent of the combined-profits figure in 1922 and 20.3 percent in 1923. In general, the taxation of companies furnishing gas and electricity seems relatively low compared with profits, while that of the water and telephone companies is high. The average figures for public utilities reporting were heavily influenced by the figures of the electric power companies. The average percentage that taxes took of income was 30.4 percent in 1922, and 25.2 percent in 1923.[1]

INCOME AND TAXATION OF COLORADO NATIONAL BANKS

The reports of the comptroller of the currency publish figures relating to income and taxes of Colorado national banks. It is difficult here, as in the previous case, to secure figures that are closely comparable with the figures for agriculture that have been presented.

[1] See page 81.

Table C[1] contains two income figures for each of the years from 1919 to 1926 for the national banks of the state outside of Denver and Pueblo, and for those in Denver and Pueblo. The first of these income figures, designated "net earnings (before deducting taxes)" represents the year's business before taking into account losses charged off or recoveries on assets that have been previously charged off. It may be roughly compared with operating profits in certain other lines. The net additions to profits figures take into account losses charged off and recoveries. For the years since 1921 the differences between these figures have been marked, due to the large losses of the deflation period which have been charged off in each of the successive years. The banks have suffered along with the farmers during this period.

One important fact relating to the tax burden on banks remains constant thru the whole period since 1919. The percentage of profits taken by taxes is higher on the country banks than on those of Denver. Only in the year 1921 did taxes take over one-third of the profits of the latter banks. From 1921 on, country banks have paid over one-third of profits in taxes and from 1923 thru 1926 have paid over two-thirds. The fraction of net earnings taken by taxes from the Denver banks rose above one-fifth only in the years 1919, 1921 and 1923. For the country banks it has been between one-quarter and one-third in each of the years from 1921 to 1926, inclusive. The reports from the two Pueblo banks are not examined in detail as they represent a very small part of all the national banks of the state. Except for heavy losses in 1922 and 1924 they show no great divergence from the general trends.

By combining the figures for all the national banks of the state there has been computed an average figure, in which the Denver banks have about as much weight as all the other banks. The percentage of taxes to net additions to profits of all the national banks was 21 in 1919. It increased to 52 in 1922, dropped to 36 in 1924 and increased to 46 in 1926. The percentage that taxes were of net earnings showed much less variation. It was 19 in 1919 and had by 1923 increased to 28. It dropped the following year to 19, rising in 1925 to 24 and declining in 1926 to 21.

While the bank figures that have been presented must be used with caution in comparisons with other figures, they do show fairly heavy taxation of current income of country banks with much less burdensome taxation for Denver banks and very heavy taxation of net additions to profits in recent years for the country banks, together with fairly heavy taxation of the Denver banks on this basis.

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1 See page 82.

No attempt will be made to examine the reasons for these differences. Attention, however, is called to the ease with which banks may be assessed, as one of the reasons why bank taxation may be expected to be higher than that of many other classes of business.

INCOME AND TAXATION OF COLORADO CORPORATIONS

No attempt will be made here to outline in detail the types of taxes to which corporations in Colorado are subject. Two, however, account for the bulk of revenue derived from corporate enterprise, the general property tax and the federal corporation income tax. Information relating to the amounts collected from corporations by these and other taxes is scanty. The only available material, aside from that which has been presented in the preceding sections, and which relates to special classes of corporations, is derived from the corporate income returns submitted to the Federal Bureau of Internal Revenue. A tabulation of these returns for corporations reporting from Colorado has been made for their income and expenses for the year 1924. This will be examined in detail and certain additional information, relating to corporations reporting profits and those reporting no profits since the year 1919, will be presented.

In considering these returns it should be kept in mind that they do not represent all corporations doing business in Colorado and that they relate to some extent to business done outside of the State. Corporations usually file their reports in the State where their principal office is located. Thus, many corporations doing business in Colorado have made their reports from other states. This is particularly true of the railroad systems that operate thru Colorado. The figures that are designated "Transportation and Other Public Utilities" in Table 5 should be considered with this qualification in mind. Some of the corporations that have their principal offices in Colorado do extensive business in other states and are taxed in such jurisdictions. For this reason the figures which are designated as "Taxes Other Than Income and Profits Taxes" and which indicate the state and local taxes paid by the corporations, contain a certain amount of taxes paid to jurisdictions outside of Colorado. While these qualifications need to be considered, it is safe to assume that taxes paid in Colorado and profits made on Colorado business constitute most of those considered in the discussion that follows and that a fair sample of corporate tax conditions within the state is given. It is necessary to remember that much of the business of the state is not carried on by corporations. The results of such business are of course not included in the figures that are given.

It will be desirable in the first place to consider figures relating to the number of corporations reporting net income and those that

reported failure to earn net income during the years from 1919 to 1925. (Table D[1]). In no year since 1919 have half of the total number of corporations from Colorado reported that their operations yielded them some net income. The years 1919 and 1925 show the highest proportion making such reports with 46.4 percent and 46.6 percent respectively. In 1921 only 35.7 percent of the total reported net income. The corporations reporting some net income in 1925 had a total gross income of over $760,000,000 while those reporting no net income had a gross of slightly less than $162,000,000. In other words, the corporations that did not earn a net income for their stockholders were on the average less than one-quarter of the size, if size is judged by gross income, of the corporations that made a net return.

When the corporation returns of the three-year period, 1923-1925, Table E[2], are considered by industrial groups, certain significant facts are discovered. Mining and quarrying corporations are lowest in the percentage of the total reporting net income. The corporations classified as agricultural are next altho there has been a decided improvement during the period in the number of such corporations that reported net income. Except for a single year, 1923, and a single group, Transportation and Other Public Utilities, there is no case in which less than half of any other group failed to report net income. Corporations engaged in wholesale and retail trade made the best showing with from 60 to 66 percent reporting net income. The data on corporations that have been presented thus far are not in sufficient detail to make possible detailed conclusions as to the relative profitableness of the various types of corporate industry in Colorado. They are, however, sufficient to indicate that there are differences in the income-producing powers of corporations, just as there are between farms, and that lack of net income is not confined to any single class of business.

A comparison of income and taxes is, however, of chief interest for present purposes. Table 5 contains figures for 1924, making such a comparison possible. Three groups, agricultural and related industries, mining and quarrying, and construction companies, reported a deficit before paying taxes. Of the important remaining industrial groups, transportation and other public utility corporations paid over 54 percent of their net income in state and local taxes and over two-thirds in all taxes. The group designated professional, hotel, amusement, etc., paid 31 and 39 percent, respectively, of its net

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1 See page 82.

2 See page 83.

TABLE 5.—Income and Taxation, all Corporations Reporting, Colorado 1924.[1]

Industrial group	Net profit before deducting taxes	Taxes other than U. S. income and profits taxes	Percentage taxes other than income take of net profits	All Taxes	Percentage all taxes take of net profits
	Dollars	Dollars	Percent	Dollars	Percent
Agriculture and related industries	–1,133,189	422,386	....	439,258	....
Mining and quarrying	–4,369,247	792,078	....	1,074,765	....
Manufacturing	36,564,565	4,571,460	12.5	8,271,438	22.6
Construction	–53,075	35,974	....	59,251	. ..
Transportation and other public utilities	7,610,592	4,129,959	54.3	5,088,115	66.9
Trade	7,262,855	1,709,910	23.5	2,508,904	34.5
Professional, hotel, amusement, etc.,	1,314,776	401,318	30.5	516,198	39.3
Finance, banking, insurance, etc.	22,573,434	3,242,588	14.4	4,371,353	19.4
Combinations, predominant industry not ascertainable	8,118	65,763	810.1	66,251	816.1
All corporations	69,777,940	15,471,451	22.0	22,395,548	32.1

[1]Computed from data supplied by the United States Bureau of Internal Revenue.

income in state and local taxes and in all taxes. At the other extreme are manufacturing which paid 12.5 percent in state and local taxes and 23 percent in all taxes, and finance, including banking, insurance and realty corporations, which paid 14 percent of their net income to state and local jurisdictions and 19 percent to all governmental units. A combination of the figures for all corporations reporting indicates that they paid 22 percent of their net income in state and local taxes and 32 percent in all taxes.

Detailed figures are available for a number of different groups in the manufacturing industry of the state. They appear in Table 6. It will be seen that there is a wide difference in the relationship which exists between taxes and net profits within this industry Those concerns engaged in manufacturing food products, tobacco and beverages, in printing and publishing, in the manufacture of stone, clay and glass products, and in the manufacture of chemicals, show ratios of total taxes to net profits lower than the average of the industry of the state.

The relationship between local and state taxes and net profits is, however, of particular interest. Printing and publishing corporations reported only 3.3 percent of net profits paid in state and local taxes. Corporations manufacturing stone, clay and glass products paid 5.2 percent and those manufacturing food products 9.5 percent. At the other extreme is a group of corporations engaged in the manufacture of metal and metal products which paid 72.4 percent.

No attempt will be made here to draw definite conclusions from these figures. The subject needs more study before this can be done. The extremely low ratio in the printing and publishing industry is due to the low investment of the industry in real estate. In the food manufacturing industry a similar tax situation is probably due to the fact that much of the real estate of the industry is situated outside of the limits of cities and is thus subject to a lower tax rate and possibly to a lower valuation than is the property of many other industries.

TABLE 6.—Income and Taxation of Corporations Engaged in Manufacturing, Colorado, 1924.

Division of Industry	Net profits before deducting taxes	Taxes other than U. S. income and profits taxes	Percentage taxes other than income take of net profits	All Taxes	Percentage all taxes take of net profits
	Dollars	Dollars	Percentage	Dollars	Percentage
Food Products	20,065,002	1,913,281	9.5	3,959,155	19.7
Textiles	81,997	23,089	28.2	32,928	40.2
Leather	49,059	8,094	16.4	12,879	26.0
Rubber	253,892	132,205	52.1	148,139	58.4
Lumber	118,912	67,574	56.8	105,639	88.8
Paper and Pulp	-41,410	4,513	.....	5,160	.....
Printing & Publ.	2,065,752	68,603	3.3	313,354	15.2
Chemicals	8,597,892	1,010,885	11.8	1,872,416	21.8
Stone, Clay & Glass	3,789,962	196,737	5.2	599,770	15.8
Metal & Metal Prod.	1,523,823	1,102,977	72.4	1,157,669	76.0
All Other	59,234	43,502	73.4	64,329	108.6
Total Manufacturing	36,564,565	4,571,460	12.5	8,271,438	22.6

The examination that has been made of the taxation of corporations in 1924 reveals the fact that there is a great diversity among them, both so far as their taxes and so far as their profits are concerned. If information were available for individual corporations, it would doubtless be possible to show that some corporations were paying such a small percentage of their net profits in taxes that this item is of little importance in the corporations' annual budgets. Other corporations could be shown to be paying an exceedingly large part of their net profits in taxes, and the large group of corporations reporting a deficit before paying taxes would present a worse picture. Similar information was presented for investments in farm land in Colorado. In considering the corporate tax situation, it should be recalled that the amounts spent for taxes represent on the average a relatively unimportant part of the total receipts of a Colorado corporation. For corporations as a whole, state and local taxes took in 1924 only 1.7 percent of the total receipts and all taxes only 2.5 percent. In the case of agricultural and related corporations the figures were 6.4 percent and 6.6 percent respectively; in the case of mining and quarrying corporations, 1.3 percent and 1.8 percent.

In general, these figures would seem to indicate that only in exceptional cases can taxation in Colorado be assigned as a major cause

of a corporation's failure to make profits for its stockholders. It seems hardly possible that a single item which on the average takes about one-sixtieth of the total receipts, as does the state and local-tax item, can be the chief or even a very strong influence in determining the success of the average corporation.

State and local taxes have been shown to take on the average slightly over one-fifth of the net profits of all corporations reporting from Colorado. The ratio of taxes to profits varies greatly among classes of corporations and could no doubt be shown to vary even more among individual corporations if data for them were available. As a percentage of total receipts, however, state and local taxes make a very slight showing, amounting to 6.4 percent in the case of the group where the percentage is highest and averaging only 1.7 percent.

In corporation taxation, just as in farm taxation, it seems entirely reasonable to assume that cases of hardship would be lessened by a form of taxation which placed more emphasis on the ability of the corporation to pay taxes and less on certain tangible evidences of the corporation's property. In the case of corporations, as in the case of agricultural property, income is probably the best single indication of ability to pay taxes and a greater reliance on this indication would make possible a fairer corporation tax system in Colorado.

RELATIVE TAX BURDENS IN COLORADO

A comparison of relative tax burdens among the different groups in any particular place or among different localities involves a comparison of so many divergent factors that any simple and obvious conclusions are to be viewed with suspicion. The definition of tax burden itself is no simple matter. How is it to be measured? What units of comparison between different groups are valid? How may benefits from taxation be related to tax payments and results expressed in quantitative terms? No single answer to any of these questions exists.

The usual basis for considering tax burden is a comparison of taxes and income. In a section where governmental services are all similar, such a comparison is of some significance. It should, however, be remembered that even in this case two individuals or groups paying the same percentage of taxes may be burdened unequally. The cases of two individuals with net incomes of $1500 and $150,000 each illustrates this. Taxes that take $150 of the former's income are commonly considered vastly more burdensome than taxes that take $15,000 from the latter. In each case, however, the percentage taken is ten. If there be added to the difference in individual incomes

differences which come from varying services supplied by the government, then the situation becomes much more complicated and, as has already been said, no definite measure of comparison exists.

From one point of view a fairly satisfactory comparison of relative tax burdens may be made. The subject may be considered from the point of view of an investor. The possible alternative investments of his money and the effects of taxes on net yield will be calculated. The assumption will be that there are presented for consideration several possible investments each yielding the definite amount of $1,000 a year before taxes are paid. It must be admitted that many considerations other than taxes will help to determine the desirability of the various investments. These other considerations must be put aside, however, so far as this discussion is concerned and attention paid exclusively to the tax features of the various investments.

The average investor in farm land in Colorado will find that taxes take approximately one-third of his net income from this source. The owner of rented city property in certain sections of the state paid on the average 28 percent of his net income in taxes. The owner of stock in an average public utility corporation of Colorado found in 1923 that one-quarter of what otherwise might have been devoted to dividends for him and to surplus for his protection was paid out by the corporation in taxes of all kinds. The previous year taxes had taken a somewhat larger portion of net profits. The owner of national-bank stock found that for the three years, 1924 to 1926, inclusive, federal, state and local taxes took on the average about 40 percent of the net additions to profits. Banks were charging off many losses during these years and so the situation was somewhat abnormal. Manufacturing corporations in 1924 paid in state and local taxes 12.5 percent of what otherwise might have been distributed to the owners of the corporations. If federal taxes as well as local taxes be considered, the figure would be nearly 23 percent.

This comparison would seem to indicate that from the owner's point of view, the tax situation of the holder of stock of manufacturing corporations is somewhat better than that of the owner of other income-producing property of the state. It has been explained earlier in the report that no uniformity exists even within this field. The figures are averages and do not, of course, accurately describe the condition of any individual company.

One inequality of the tax system of Colorado has been demonstrated by this study and by others that have been made. This relates to the taxation of tangible property as compared with intangible. Under Colorado's present system of taxation, almost no intangible property is assessed. While this is in distinct violation of law, there seems no way by which the law can be enforced. Many people

feel that enforcement of the law in this respect would result in more injustice than does the present system. It seems unnecessary to discuss this here as there is no possibility of strict enforcement. Some means, however, should be found of forcing possessors of intangible property to pay a fair contribution toward the cost of government. This will be discussed in detail in a later portion of this report.

The data that have been compiled show little difference between the taxation of rural and of urban real estate. The figures for city real estate, however, relate to only a few towns of the state and so may be considered to cover a relatively insignificant part of the whole. The average relationship of assessed value to owners' value, for the urban and farm groups studied, will be shown to be fairly close, so no great difference arises from this score. So far as property income and taxation go, the two groups are also fairly close together.

In concluding the indecisive survey of relative tax burdens that can be made on the basis of present information, it should be emphasized that the most striking inequalities at present are those between income-producing properties that are not taxed and those which are. In the latter group, some adjustment doubtless should be made, but major attention needs to be given to those measures which will make possible a broadening of the tax base to include those types of tax-paying ability which at present are making no contribution to the support of the government.

II. ASSESSMENT OF TAXABLE PROPERTY IN COLORADO

Certain facts relating to the tax burden on different types of property in Colorado have been presented in the preceding section. The assessment of property is recognized as an important factor in determining the burden of taxation. It is therefore appropriate to consider next the methods and results of the assessment of property in Colorado. Thruout this consideration it should be kept in mind that the bulk of farm property is of a type that is easily found by assessors and for this reason does not escape taxation. Agriculture is more interested in a fair assessment of property than are those industries or individuals who possess property which is of the sort that rarely attracts the attention of the assessors and so pays little in taxes.

The general property tax in Colorado rests theoretically on the assessment and taxation of all property within the state which is not expressly exempted by law. Two groups of public officials are concerned with the assessing of property, the local county assessors and the state tax commission. The work of each of these will be described in turn.

THE LOCAL ASSESSORS

The county assessors who are popularly elected for a two-year term are the only elective officers who give direct attention to the assessment of property. They and their deputies and field agents carry out the township and municipal assessment of the entire county. All taxable property, tangible and intangible, with the exception of public utility property which is assessed by the tax commission, is supposed to be listed and assessed by them. Their assessment is reviewed by the county commissioners acting as a board of equalization. This board hears and settles such complaints relating to assessment as may be brought before it.

It is the duty of the assessors or their agents to visit between January 1 and May 20 all resident owners of taxable property for the purpose of listing, examining and assessing it. In cases where the property in question has been listed the previous year the owner is questioned concerning changes that may have occurred in its condition or value. After the examination and listing of the property the owner is required to sign under oath a schedule containing the relevant information. If the assessor has reason to believe that the statement of the owner of the property is erroneous, he may assess the property on the basis of such evidence as he can assemble. Personalty, improvements and land must be listed and assessed separately.

The assessors' records of farm real estate vary widely among the different counties of the state. In most cases there is a permanent record in abstract, or in plat or map books. This record contains the legal description of the property, locating it in section, township and range or in lot and block, if it is platted property. The abstract record ordinarily contains a division of the land into various classification groups together with the total assessed value of each class within the property. These classification groups are, however, not uniform from county to county and so do not all correspond to the classification contained in the annual report of the state tax commission. An arbitrary conformation to this latter classification is resorted to by certain of the counties in making their reports.

The abstract record contains the value of improvements along with land values. Owners' names and schedule numbers are usually a part of the abstract while in some cases it contains records of property transfers, trust deeds, mortgages and court decisions affecting the property. Roads, waste and right-of-ways are in some counties included with these records and are deducted from the gross land owned. In other counties these items are wholly or partly ignored or, where recognized, are not deducted from the whole. Mineral and coal reserves are sometimes shown in the abstracts.

The assessed valuation of the lot and the valuation of improvements appear in the abstract in the case of city real estate. Such property is described as to subdivision within the municipality by referring to the lot and block, or by meets and bounds if the property is not in a subdivided area. In some counties the abstract also contains the location on the lot of the improvements.

Assessed values of rural real estate seem at the present time to be based largely on the values used in previous years. In some counties these values are revised annually. In others they are changed only when pressure from one source or another is brought to bear on the assessors. Such revision, however, is usually based on some figures adopted in advance and only modified under exceptional circumstances. Even the reappraisement which may take place every five or six years usually consists of a percentage change based on the earlier figure at which the property was assessed. Changes in the utility of land over a period of years are seldom taken into consideration in assessment except when brought to the assessor's attention by some unusual means. General or local economic trends exercise some influence in determining the assessment figure, but it is safe to say that no two assessors consider these influences in the same light. On the whole there is the natural tendency of keeping real property at the same figure from year to year, no matter how its use or value may have changed. There are, of course, many exceptions to this, but it is characteristic of most of the counties in the state.

No attempt is made to assess or reassess real property at its full cash value. In setting a final figure each assessor has in mind a certain percentage of full cash value at which he believes he is assessing the real property of his county. An informal inquiry made of assessors in a number of different counties indicates that there is a considerable variation from county to county in the percentages which the assessors use for this purpose.

Valuations of all classes of personal property except motor vehicles, livestock and securities with a face value are arrived at more or less haphazardly. Once such property appears on the tax rolls at any value, it is likely to remain at approximately the same figure year after year. While a theoretical attempt is made to assess personal property at its full cash value, little uniformity exists among the several counties. The owners' figures of the value of this property are usually accepted unless they are glaringly out of line. Only in the case of motor vehicles and livestock is there a concerted attempt at uniformity. The former are assessed on the basis of figures of the value of new cars at the factory. These are supplied to the asses-

sors by the state tax commission. Cars that are in the first year of use at the time of assessment are given a valuation of 70 percent of this figure. Those in their second year drop to 50 percent, and in the third year to 30 percent. In most counties some cooperation exists between the county clerk and the assessor in recording the owners of motor vehicles which are reported separately from other personalty on the assessors' schedules and rolls. There is, however, no automatic check whereby license tags can be secured only on the presentation of the previous year's tax receipts.

Livestock valuations are quite uniform thruout the state, but there is no pretense that they are made on the basis of full cash value. Figures to be used each year are generally discussed and agreed upon by the county assessors at their annual meeting.

From what has been said it will be easily understood that both methods of assessing and the efficiency of assessment differ widely from county to county. Quantity as well as quality of the recorded information varies among the different assessors, some collecting very detailed information, others being content with a very meager amount. Thus in some counties realty transfers are checked every day in order to be certain that assessment is made to the proper parties; in others all transferred property is assessed under the name of the former owner, or it is assessed "owner unknown." Field men in some counties are supplied with maps every year to check up on land classifications, changes in buildings, the location of wells and other features affecting the value of the property. In most counties, however, this is not the practice and changes are recorded more or less by chance. It has already been pointed out that there is no uniformity among the various counties in their classifications of agricultural land. It is therefore necessary for some of them to make arbitrary adjustments in order to make their reports conform to the classification of the state tax commission.

While the initial assessment of most property for tax purposes is the work of the county assessors, supervision and certain definite duties belong to the state tax commission. The section that follows will explain the commission's part in the assessment system of the state.

THE COLORADO STATE TAX COMMISSION

The Colorado State Tax Commission, which was authorized by law in 1911, consists of three members appointed by the governor and treasurer for a term of six years. According to law, one vacancy occurs in each biennial period and one appointment must therefore be made every two years. A knowledge of and training in the sub-

ject of taxation are qualifications which are taken into consideration in the selection of men who are to serve as members of the commission.

The duties and powers of the state tax commission which relate directly to the local assessment of property will first be set forth in detail, and then certain other aspects of the commission's work will be considered. The law provides that the state tax commission shall have:

(1) General supervision over the administration and enforcement of all laws for the assessment, levying and collection of taxes. To this end the commission shall exercise supervision over the county assessors, boards of county commissioners, county boards of equalization and all of the boards of assessment, levy and collection so that all assessment of property, real and personal and mixed, may be made relatively just and uniform and at its true and full cash value. It shall have the power to require all county assessors, county commissioners and county boards of equalization under penalty of forfeiture and removal from office as such assessors or boards to assess all property of every kind or character at its actual and true cash value.

(2) The duty of preparing and transmitting to the assessors of the several counties such forms of returns to be made by them to its office and such instructions as it deems conducive to the best interest of the state upon any subject affecting taxation.

(3) The power to prescribe a uniform system of procedure in the assessors' offices and the form and size of tax schedules, tax rolls and warrants, field books, plat and block books and maps.

(4) The right to order transcripts of records or parts thereof and other information on file in the respective offices deemed necessary by the commission.

(5) The power to investigate the work and methods of county assessors, boards of county commissioners, county boards of equalization and county treasurers in the assessment, equalization and collection of taxes on all kinds of property in the state.

(6) The power to require any assessor to appear before the commission at any of its meetings for examination concerning the assessment in his county.

(7) The duty of calling an annual meeting of the county assessors to be held at the State Capitol or to call group meetings of two or more assessors at such time and place as it may designate.

(8) The right to appear and be heard in any court, or tribunal in any proceeding in which abatement or refund of taxes is sought.

Each of the commissioners, the secretary and agents employed are invested with all the necessary powers which are required in the securing of the records and facts that are to be used in the appraisal and valuation of property, real and personal.

It is the duty of the commission, on or before the first day of October each year, to determine whether the real and personal property of each of the several counties in the state shall have been assessed at true and full cash value and if in the opinion of the commission the real and personal property within any county in the state as reported by county assessor to the commission is not on the assessment roll at its true and full cash value the commission shall determine the increase or decrease in the valuation in such county by such rate in percentage or such amount as will place this property on the assessment roll at its true and full cash value.

When the commission has determined the true value of the real and personal property in the several counties the commission transmits to the state board of equalization a statement of amount to be added to or deducted from the valuation of the real and personal property of each county, specifying the amount to be added or deducted from the valuation of the real and personal property.

It is the duty of the state board of equalization, which consists of the governor, auditor, treasurer, secretary of state and attorney general, to examine the abstracts of assessment as submitted by the state tax commission. The board approves the abstract for each county, or makes such changes as it deems necessary. A record of its action is made on the abstract for each county and this is certified to the county assessor. He is required to make such changes in the valuations of each tract or lot and its improvements and of all personal property as the state board of equalization shall direct. Assessments are adjusted to the nearest $10.00 unit.

Two other duties of the state board of equalization should be mentioned in this connection.

(a) The right to make reappraisement of property in cases where it appears that property in any county or municipal subdivision thereof has not been assessed at its true and full cash value and to require assessors to place upon the assessment roll any property which may have escaped taxation.

(b) The duty of raising or lowering the assessed value of any real or general property, first giving notice to the owners thereof and fixing a time and place for hearing to the end that the assessment laws of the state be equitably administered.

The state tax commission is also charged with the duty of assessing for taxation the property of railroad, telegraph, telephone, express, private car and other public-utility companies. In many cases the business and properties of such companies extend into many counties of the state and a fair valuation can only be made by an assessor or group of assessors who can consider the state as a whole. The tax commission determines the value of a utility as a whole and apportions this value on an equitable basis among the counties served. The valuation for the county is then distributed among the local taxing districts by the county commissioners and taxes are levied on the basis of the rates that apply to each unit.

RESULTS OF THE WORK OF THE ASSESSORS

KINDS OF PROPERTY ASSESSED.—The methods of assessment that are in use in Colorado have been described briefly. The next step in an attempt to understand and appraise the tax system is an examination of the way the assessment system has worked. What are its results? What kinds of property have the assessors discovered and placed on the tax books? Partial answers to these questions can be obtained from a study of the annual abstracts of assessment which are assembled in the reports of the Colorado tax commission. Table F summarizes the abstracts for certain recent years.[1]

Two striking facts which will be confirmed by the experience of the individual taxpayer are revealed by an examination of this table. Very little property that is not tangible is discovered and reported by the assessors. It will be recalled that the tax laws make all property, tangible or intangible, subject to the same assessment and taxation. Of the groups listed in the table only two may be described as intangible, namely, bank stocks and money credits and accounts. These amount to only about 2.8 percent of the total assessed value of the property in the state in 1925. If bank stocks be omitted from

1 See page 84.

consideration less than 1.6 percent of the total assessed property is found to be in the intangible classification. There will be a more detailed discussion of this later in the report.

The second important fact that emerges from an examination of Table F is the overshadowing importance of real estate in the property valued by the assessors. In 1925, classifications comprising two-thirds of the assessed property of the state were composed wholly of real estate. The additional class, corporations assessed by the tax commission, is made up to a considerable extent of real estate and probably brings the proportion of real estate to total property assessed up to three-fourths. This fact makes a study of the changes in the assessed valuations in this special class of property of great importance in any consideration of the taxing system of the state.

Table 7 shows four classes which are composed wholly of real estate: (1) Land and improvements; (2) town and city lots and improvements; (3) metalliferous mining property; (4) timber, coal and oil properties. The first two of these include most of the real estate and particular attention may be paid to them. Land and improvements might well be given the designation of "farm real estate." It amounted to 32.2 percent of the total assessed property of the state in 1925. Its proportion of the total had shown a steady decline of a small amount each year since 1921 when it stood at 34.8 percent of the total. It had risen materially from 1918 when it was 28.6 percent of the total. In 1912, it had been 21.3 percent, and the following year 24.7 percent of the total assessed value of the property of the state. Emphasis should be placed on the fact that there is no evidence which definitely indicates that the proportion of the earlier years was in closer accord with the actual situation in the state than the proportion in recent years. The figures are presented to give an understanding of the situation that exists and not to condemn or to justify it.

City real estate in 1925 comprised 31.1 percent of the total assessed property of the state. Its proportion to the total had shown a small increase each year since 1920 when it had amounted to 25.7 percent of the total. It was a slightly greater proportion in each of the two preceding years. In 1912 and 1913, however, it had accounted for a far greater proportion of the total assessed valuation of the state, amounting to 40 percent and 35.6 percent respectively.

Enough has been said to indicate the large importance of ownership of either city or farm real estate in determining an individual's liability to contribute toward the support of the government. It is safe to estimate that for the last five years over three-fourths of the proceeds of general property taxes came from real estate. The gen-

TABLE 7.—Percentage that the Assessed Valuations of Different Classes of Property in Colorado were of the Total Assessed Valuation, 1912, 1913, 1918-1925.[1]

Class of Property	1913	1914	1918	1919	1920	1921	1922	1923	1924	1925
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Lands and Improvements	21.27	24.71	28.57	31.20	33.09	34.84	34.37	33.76	33.27	32.22
Metalliferous Mining Properties	4.27	3.52	2.36	1.98	1.71	1.57	1.57	1.55	1.50	1.50
Livestock	4.26	4.86	8.06	7.66	6.46	4.37	4.06	3.61	3.18	3.05
Timber, Coal and Oil Properties	1.98	1.57	1.86	1.66	1.53	1.61	1.42	1.58	1.70	1.86
Town and City Lots and Improvements	40.00	35.60	26.81	25.80	25.66	26.53	27.71	28.92	29.92	31.06
Corporations Assessed by Tax Commission	14.44	19.92	17.27	15.51	14.30	14.35	14.60	14.77	14.81	14.76
Merchandise	3.95	3.68	5.62	6.18	5.80	5.54	5.15	5.17	5.22	5.26
Capital Employed in Manufactures	0.83	1.04	2.06	2.13	2.48	2.60	2.50	2.42	2.58	2.49
Bank Stock	1.84	2.21	1.70	1.72	1.82	1.97	1.93	1.93	1.68	1.62
Money, Credits and Accounts	0.97	0.86	4.30	4.43	4.28	1.24	1.21	1.19	1.29	1.15
Miscellaneous (less exemptions)	6.19	2.03	1.39	1.73	2.87	5.38	5.48	5.10	4.85	5.03
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1]Computed from figures appearing in the Annual Reports of the Colorado Tax Commission.

eral property tax is the only important tax levied for school, city and county purposes, and it is also an important feature in the support of the state government.

At an earlier period, when the ownership of real estate was a satisfactory indication of tax-paying ability, no great objection could be made to this method of supporting the government. At the present time, when ownership of real estate taken by itself is far from being a satisfactory criterion of tax-paying ability, any system that places such great reliance on this single source is in sore need of change. This would be true if the assessment of real estate and of other types of property were working in a way which approached perfection. It is of more striking importance when it is certain that the present system is not equitable and when there is doubt whether any minor revision that is feasible would be sufficient to correct inequalities. The paragraphs that follow will point out some of the inequalities among holders of real estate and among holders of other types of property.

Relation of Assessed Value to True Value

As this report has already stated, real estate is not assessed according to the letter of the law, that is, at full value in cash. Court decisions have held that such value shall be equivalent to fair sales value. No attempt is made to attain this 100 percent assessment and it is very probable that it would not be possible to maintain a full assessment on this basis over any great period of time. That actual procedure differs from the letter of the law would not be important if the departure from the statute were the same from one property to the next, from one district or municipality to the other, or finally from one county to another.

Unfortunately authenticated sales figures are difficult to obtain without an excessive expenditure of time and money. In the present study, owners' valuation figures were used. These figures were secured as an answer to the following question; "At how much would you offer this property to a buyer who didn't have to buy and supposing that you didn't have to sell, knowing your land as you do in comparison with other agricultural land in this area?" It is felt that the answer as given in most cases approached the full cash value of the property in question. In order to check these answers the valuations were verified by other men in the neighborhood who valued their own land at a like amount, unit for unit. It is believed that the owner-valuation figures are, on the whole, comparable, one with another, over the areas covered but it should be emphasized that these figures are not sales figures.

Figures were secured from the following districts in the State: Northeastern Colorado, Western Slope, San Luis Valley and Arkansas Valley. The district summaries appear in Table 8. In each of these districts enough records were secured that a representative cross-section might be shown. Assessed valuations were secured for the property for which owner's valuation figures had been secured. Districts were found to vary appreciably, considering assessed valuations expressed as a percentage of owner's value. In 1925-26 the range between rural districts was from 80 percent in the Harmony district of northeastern Colorado to 34.6 percent in the Montrose district of the Western Slope. This indicates a range of 45 percent from the highest to the lowest district.

The areas in northeastern Colorado were assessed uniformly at a higher figure in comparison to the owner's value than were the areas in the other sections studied. In only one instance does an area outside of northeastern Colorado show a higher percentage than an area in that district. Rural real estate in the Delta County area was assessed at 53.6 percent of owner's value in 1925-26 while the lowest percentage among the areas of northeastern Colorado, the Akron district, shows a percentage of 53.2 percent.

TABLE 8.—Relationship of Owner's Valuation and Assessed Valuation, Rural Property, by Districts, 1920 and 1925-1926.

1920

District	Number of records	Assessed valuation as a percentage of owner's valuation		
		High	Low	Average
Northern Colorado *	262	129.3	18.0	52.0

1925-1926

District	Number of records	Assessed valuation as a percentage of owner's valuation		
		High	Low	Average
Northern Colorado *	359	531.6	14.6	64.7
Arkansas Valley	10	71.3	22.4	49.1
San Luis Valley	21	122.8	29.0	40.7
Western Slope	30	117.5	24.0	47.0
All Districts	420	531.6	14.6	61.0

*Includes the Northern Colorado District, (See Figure 2) and Washington, Yuma and Phillips Counties.

Considering the figures for urban real estate which were secured in typical towns in the four sections studied together with Colorado Springs, one of the larger cities in the state, we find urban real estate assessed at a higher percentage of owner's value than is rural property. The range of the district averages is from 40.7 percent in Monte Vista to 132.8 percent in Rocky Ford. This indicates a

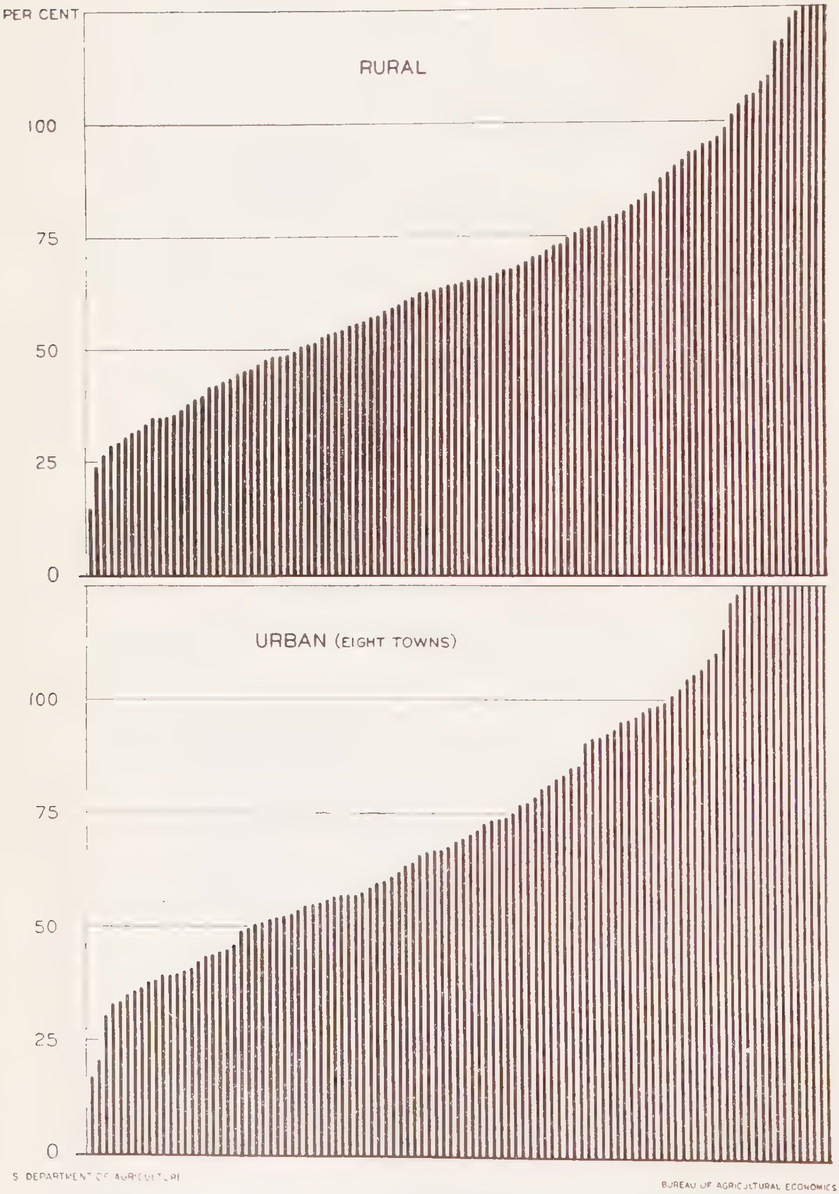

Figure 5.—Comparison of the Ratio of Assessed Value to Owners' Estimated Value for Individual Prices of Rural and Urban Real Estate, 1925-1926. Each bar of the rural section represents four pieces of farm property. Each in the urban section represents two pieces of town or city property. The striking fact in each part of the chart is the wide variation of the relationship between assessed and owners' values.

spread of 92 percent from high to low urban. These figures appear in Table 9.

The greatest significance of the owner's valuation figure lies in its comparison with the assessed-valuation figure from one property to another rather than from one section of the state to another, or from one district to another. It is in this connection that the greatest variations are apparent, indicating that the present methods of assessment are inadequate to compare properties uniformly. Figure 5 illustrates these variations.

TABLE 9.—Relationship of Owner's Valuation and Assessed Valuation, Urban Property, by Districts, 1920 and 1925-1926.

1920

District	Number of records	Assessed valuation as a percentage of owner's valuation		
		High	Low	Average
Arkansas Valley	28	232.9	83.2	135.3
Northern Colorado	22	80.1	13.3	42.1
Plains	28	195.0	26.1	68.2
San Luis Valley	21	97.0	40.9	57.5
Western Slope	90	207.7	18.0	82.0
All Districts	189	232.9	13.3	65.2

1926

District	Number of records	Assessed valuation as a percentage of owner's valuation		
		High	Low	Average
Arkansas Valley	28	232.9	83.2	132.8
Northern Colorado	38	99.3	19.5	46.4
Plains	28	98.4	30.3	66.8
San Luis Valley	21	83.3	32.9	57.1
Western Slope	90	193.6	16.9	76.8
All Districts	205	232.9	16.9	63.6

The 420 rural properties studied in 1925-26 reveal that assessed valuation as a percentage of owner's valuation on individual properties ranged from 14.6 percent to 531.6 percent. It is recognized that the extreme variations at either end of the scale may be unrepresentative and the highest 10 percent and the lowest 10 percent have been disregarded. This gives a range from 35.0 percent to 106.0 percent for the remaining 336 properties and indicates a spread of 71 percent from high to low. The average valuation for the 420 farms was 61.0 percent. More than half of the farms are grouped between 40 and 80 percent, nearly 28 percent of them falling between 60 and 70 percent.

The 205 urban properties studied in 1926, indicated a range in assessed valuation expressed as a percentage of owner's valuations from 16.9 percent to 233 percent. Omitting 10 percent of the cases at either end, the range is from 38.8 percent to 130 percent. The average

percentage is 63.6. Fifty percent of the properties are grouped between 50 and 90 percent, about 25 percent of them falling between 50 and 65 percent. In comparing the average percentage that assessed value is of owner's value for urban properties, with the average percentage for rural properties, it is seen that the former is nearly two and one-half percent higher than the latter.

When the assessed valuation of rural real estate in northeastern Colorado, expressed as a percentage of owner's valuation for 1920, is compared with that secured for 1925 in the same section, it is noted that the 1925 percentage is 12 percent higher than the one for 1920. This indicates that assessed valuations were greater in comparison to owner's values in 1925 than in 1920. When the assessed valuation of urban real estate, expressed as a percentage of owner's value for 1920 and 1925, is considered, we find only a slight change. In other words, these figures indicate that there has been a more constant relationship between assessed values and owners' values in the urban sections than in the rural ones. This may have resulted from a closer adjustment of assessed values in the cities, or it may have resulted simply from the fact that during the period under discussion owners' values of farm land have been subject to greater change than have values of urban land.

THE ASSESSMENT OF PERSONALTY.—About 12 percent of the property assessed by the local assessors may be classed as personal property. In Table F the groups designated livestock, merchandise, capital employed in manufactures, bank stock, money, credits and accounts and miscellaneous all include personal property. The miscellaneous group needs somewhat more detail than appears in Table F. Its total in 1925, before deducting exemptions, was $111,219,000. The two chief items in this total were automobiles and household property. These accounted for 42 and 26 percent respectively, of the whole amount. Other classes of importance were furniture and fixtures of business properties with 11 percent of the total, agricultural implements with 8 percent, and musical instruments with 6 percent. Several small groups made up the rest.

It has been said earlier in this report that the assessment of livestock and of automobiles is fairly uniform among the various counties. In much of the rest of tangible personalty there is little basis for a real comparison. Assessment is more or less by chance. A piece of property once on the books is apt to stay there without a change of value over a period of years.

A single example will give an indication of the situation. The number of clocks and watches assessed in the state was recorded in 1925 as 18,355. That is, one person in every 55 owned a clock or

a watch, if we are to believe that the assessors found all property of this class. If this is the situation, the inhabitants of Colorado must have difficulty in telling time. The lack of any uniformity is further revealed by the variation in average value of clocks and watches in the counties from \$4.64 to \$38.63. This is an unimportant group so far as the state's assessment is concerned, but its absurdities illustrate the haphazard way in which some types of tangible personalty are assessed.

When attention is turned to the types of intangible personalty a far worse situation is revealed. The items "bank stock and money" and "credits and accounts" include the intangible property that is assessed. The bank-stock item offers no difficulties to the assessors as banks in the state are required to make reports and taxes are collected from the banks as agents for the stockholders. The money, credits and accounts item which in 1925 was about two-thirds as much as the bank-stock item, illustrates the almost complete failure of the general property tax to reach intangible property. In this item are supposed to be included bank deposits, money, credits, bank accounts, accounts not evidenced in writing, promissory notes, bonds, debentures and all other evidence of indebtedness. No reliable figures of the actual amounts of most of these types of property are available for the state. No one would be naive enough to pretend that the "money, credits and accounts" item of under \$18,000,000 in 1925 represented any substantial amount of the property of this type that should be assessed under the provisions of the law as it stands at the present time. Some county assessors appear to make no attempt to include anything in this class. Others include some small amounts of no real value so far as tax contribution is concerned.

For the one class of intangible property, bank deposits, definite data exist. In 1925, the aggregate bank deposits of the state not including governmental deposits, amounted to about one quarter of a billion dollars. All of this and such deposits as residents of the state have in banks outside of the state are subject to assessment and taxation after certain debts of the taxpayer have been deducted. For the state as a whole, in 1925, bank deposits were reported by the assessors as amounting to less than \$7,400,000 and this included all money, credits and book accounts for Denver and Cheyenne counties. The amount properly assessed as bank deposits would probably be about \$5,000,000. For a few counties chosen at random the figures are of interest and are contained in Table 10.

No student of the subject will deny that the attempt to reach other classes of taxable intangible property has met with the same lack

TABLE 10.—Bank Deposits and Assessed Value of Bank Deposits in Several Counties of Colorado, 1925.[2]

County	Bank Deposits	Assessment of bank deposits
	,000 omitted	,000 omitted
Alamosa	$ 1,333	$ 3
Denver	143,093	5,559[1]
Elbert	918	6
Las Animas	8,775	33
Washington	1,018	11

[1] Includes, money, credits, etc.

[2] Bank deposits from reports of Comptroller of the Currency and Annual Report of the State Bank Commissioner of Colorado (for a single call date in 1925). Average figures would be slightly different, but would make no change in the general conclusions. Assessment figures are taken from the Annual Report of the Colorado Tax Commission. Figures for additional counties would illustrate some slight differences among them, but would mainly show an almost complete lack of any real success at taxing this type of property.

of success that has been shown with reference to bank deposits. This is not a criticism of the assessors. They have been given an impossible task and they can not be expected to succeed in accomplishing it. Public opinion, rightly or wrongly, believes that the general property tax is unfair as it applies to intangible property and where it is necessary individuals will cheerfully perjure themselves in order to escape what they consider an unjust tax. The fact that most of this property can be discovered only when the individual owner is willing to return it makes any material improvement in assessment impossible until the method of taxing is changed.

A brief summary should be made of certain inequitable results of the attempt to tax intangible property under the general property tax as it exists in Colorado at present. Owners of intangible property who, because of honesty, necessity or ignorance, return their property to the assessor have it valued at a high percentage of its real value and pay a tax on it which takes a high proportion of its income. Owners of bank stock have been compelled to be in this situation and are at a disadvantage compared with owners of stock in other corporations that pay similar returns before considering taxes.

The contention here is not that intangible property should pay no taxes. Ownership of such property is a very real indication of ability to pay taxes. The fact, however, is that intangible property in Colorado pays almost nothing and that the method by which some small amount of taxes is collected from its owners makes injustice the necessary result. Methods of altering this situation will be discussed later. Under the present system no great change for the better seems possible.

POSSIBILITIES OF IMPROVING THE ASSESSMENT SYSTEM

Any discussion of the ways by which the assessment system of Colorado may be improved must primarily consider the assessment

which is made by the local assessors. Inter-county adjustment for equalization purposes will always be necessary, so long as county assessments have any importance to the state, but in so far as the system can be improved in the counties, the need for state adjustment is reduced. It should at the outset be pointed out that no attempt is made to discuss ways of improving the assessment of intangibles. This problem must be met by changes in more than assessment practices.

The most important feature in the assessment system is that of personnel. There is general agreement among those who have studied the subject that properly appointed assessors can be superior to elected assessors. This does not mean that the simple changing of the assessor's office from an elective to an appointive one will necessarily improve the system. If assessors are to be appointed, their selection must be based on training and knowledge rather than on political service. It would be desirable to have assessors appointed by the county commissioners and approved by the tax commission or by some other state body which could make definite experience and training qualifications which all appointees must satisfy. Appointments must necessarily be for a term of at least six years. The present two-year term is obviously not long enough to give the assessor time to do more than become acquainted with the duties of his office. This is recognized by many counties where assessors are reelected to successive terms. If assessors are appointed for long terms, provision should be made for removal for cause by the county commissioners with the right of appeal to some impartial group not connected with fiscal affairs, possibly the supreme court of the state.

Along with the change in the method of appointment of the assessor should come an increase in his annual salary. It may be true that certain counties cannot afford a well-paid assessor. They can even less afford a poorly paid one. An adequately trained man may be able to handle the work of more than one of the smaller Colorado counties. If consolidation and rearrangement of counties do not solve the question, it should be possible for adjacent counties to solve it by agreement. This may involve some loss as far as local pride and a position for a local man are concerned, but an improvement in the assessment system of any county should more than repay for a loss of this sort. The annual salary should be enough to induce a man to devote himself solely to the work and to make him regard it as a permanent profession. It is only by such inducements that men of training and experience can be induced to continue in this rather thankless position.

It should be understood that these recommendations do not imply that the present assessors of Colorado are unfitted for their posi-

tions. The writers feel that Colorado is unusually fortunate in its assessors, but that a better and surer method could be adopted for finding the right men. It would be unfortunate, however, if a new system should fail to make use of the many adequately trained and experienced men who hold the office of assessor at the present time. While the man who directs the work is of supreme importance, it is believed that without a change in the methods of appointment, marked improvements can be made in the work of most of the assessors' offices. Means by which such improvement may be brought about will be suggested in the following paragraphs.

Whether one is to consider inter-county equitability or intra-county equitability, adequate uniform records are essential. A permanent file should be maintained subject to constant revision. Some of the more important items of information which should be available at all times are the following: Court decisions, decrees, contracts, deeds and all legal instruments affecting the ownership of of real property within the jurisdiction of the assessor. This information, if secured regularly from the county clerk and other recording offices, can be made easily available. It might be well to keep a separate file of trust deeds, mortgages and warranty deeds which relate to real property in the county. This information is valuable to aid in establishing values as well as fixing the identity of the owner.

A current record should be maintained as to utilization of the rural land of the county. Special attention should be given to roads, ditches and right-of-ways as these items are exempt by law from taxation. In practice these items are, in many counties, assessed. A uniform treatment should be accorded waste lands and mineral reserves. In the case of waste lands these lands should be assessed at a uniform figure. Mineral reserves should be assessed to the owners of these reserves and this value should be deducted from the assessment of the remainder of the property value. In irrigated districts it would seem advisable to maintain a permanent file of water-right priorities, ditch stock, and reservoir stock pertaining to any body of irrigated land. Water rights are an extremely important part of total land value in irrigated districts.

Land should be classified as to fertility or potential utility uniformly over the state. The merits of such a system are obvious. In discussion of factors affecting classification, a standard is essential. Inter-county equality is another consideration which would seem to require uniform classification. State tax commission reports which contain a summary of the county abstracts should be based upon uniform classification. Such is not the case at present. Record should be made of land classifications and such records should be modified each year on the basis of the fieldmen's reports. Since

enlightened assessment is based upon adequate information it is essential that land of uniformly inferior quality be distinguished from spotty land or land which is poor in spots only. It is probably true that an assessor or his deputy may remember whether a piece of land is assessed low because uniformly worn out or because it is spotted with hardpan. The successors of this assessor or any outside authority will not have this knowledge nor will they be able to act intelligently should any question of classification arise.

Altho assessment of rural property for the purposes of taxation has been largely a guess, it does not follow that any guess is a good guess, nor does it follow that being so largely a matter of guess, aids in the form of score cards and detailed information should be shunned. Rather, assessment which is as scientific as possible is the only possible means of securing relative fairness and uniformity.

Scientific assessment first supposes some standard or standards of value. Whether this standard should be full cash or sales value is perhaps doubtful, even tho so stated in the law. Since in practice real property is assessed in relation to other real property in the same area or comparable property in another area, it would seem that this offered some suggestions. All suggestions here presuppose a continuation of the present system and are suggested as improvements which will make the present system more equitable.

All real property, rural or urban, should be assessed on the basis of a score card. In the case of rural properties those factors should be considered which are considered by a prospective buyer in sizing up the property. Among these factors should be considered distance from market or railroad, type of road, possibilities for use other than as farm land; water-right priorities, reservoir stock and ditch stock if any; kinds and condition of fence and of buildings; general character of soil; proportion of total land as agricultural land; classification of all land. In different districts the practice will vary and special items will be found essential such as accessibility of free range, wells and their location, etc. In all cases it might be well to show the location of buildings on land.

Field agents should be supplied with blanks upon which the above information may be assembled, together with a section map upon which roads, ditches, waste and agricultural land may be classified. Records and maps for the previous year should be carried by the field agent in order that he may check against these. This check-up should be made annually in all its details.

After the annual assessment has been made and the abstract drawn up it would seem that some sort of an open district meeting should be held to discuss the assessments of real property in that

district. The benefit to both the assessor and the assessed would be great since it would allow them to meet on neutral ground and discuss assessments from their respective points of view.

More widespread publicity should be accorded county tax matters. The assessor has his part to fulfill in this task. Most tax notices show only the amount of the total tax levied against a certain piece of property. Some notices give the total tax of the owner assessed against all of his property and include the tax on his personal possessions as well as on his real estate. No attempt has been made to divide the total tax into its component parts. The levies for various purposes within the state, county and school district are often shown only on the back of the tax receipt, and may be examined if one should take the trouble to look on the back of his receipt after the taxes are paid. Each tax notice should contain this information and should divide the tax assessed against each piece of property into state, county and school district taxes. This would allow taxpayers to see the relative importance of the various taxes which they contribute to the support of state and local governments. It will persuade them to consider their taxes not as a unit but as a sum of several separate taxes. This understanding is essential in fixing the responsibility of the various divisions to which the taxpayers contribute. Such a system is now in operation in at least one county of the state.

III. ANALYSIS OF RECEIPTS AND EXPENDITURES

An examination of the receipts and expenses of Colorado can conveniently be made by considering first those of the state government as such and later those of the counties and local units. The reason for making such a separation is based both on the different sources from which the units derive their revenue and the purposes for which these revenues are spent. These differences will appear as the two classes are considered.

RECEIPTS OF THE STATE GOVERNMENT

The receipts of the state government may be divided into two general classes—receipts from taxes and non-tax revenue, each of which in turn will be sub-divided and analyzed. (See Table 11.) For purposes of description the year 1926 will be used as typical.[1] After the situation in that year has been made clear, a study will be made of the changes that have taken place in the last twelve years.

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[1] The years referred to in the discussion of the receipts and expenditures of the state government are the fiscal years ending November 30 of the year mentioned.

TABLE 11.—Revenue Receipts of State Government, Colorado.[1]

Revenue receipts	1926	1925	1924	1923	1922	1920	1918	1916	1914
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Total	15,295,976	15,888,116	16,065,017	15,073,975	13,858,357	10,491,019	7,019,146	5,363,861	3,641,168
Taxes									
General property	5,659,605	5,844,144	6,215,155	6.913,075	6,574,648	4,986,280	3,908,552	2,543.824	1,597,678
Special	1,146,288	1,187,271	1,157,012	993,146	817,423	832,214	552,917	815,409	363,086
Poll	122	166	131	342	....	12,591	116,503	91,757	88,693
License	3,875,172	3.562,153	3,258,379	2,256,797	1,562,875	1,438,124	611,903	422,174	400.931
Total taxes	10,681,187	10,593,734	10,630,677	10,163,360	8,954,946	7,269,209	5,189,875	3,873,164	2,450,388
Special assessments	53,558	883,414	871,404	932,282	560,281	130,083	....	....	....
Fines, etc.	4,029	18,416	19,054	19,431	30,647	28,715	6,729	2,793	17,957
Subventions, etc.	1,545,784	1,679,687	1,982,183	1,564,036	1,612,664	1,005,367	158,368	122,047	113,812
Highway privileges, etc.	1.031,797	1,061,763	989,346	1,000,577	978,920	944,325	768,051	690,144	502,317
Earnings gen. depts.	1,979,621	1,651,102	1,572,353	1,394,289	1,720,899	1,113,320	896,123	675,713	555,694

[1]Source: Bureau of Census, "Financial Statistics of States."

In 1926 taxes accounted for about 70 percent of the total revenue receipts of the state government. The remaining revenue consisted of fees, sales, rents, interest, fines, subventions, grants and gifts. The largest item falling in this second revenue group is commonly designated as earnings of general departments. It is composed mainly of fees and charges made by the various departments of the state government to those who make special use of the departments' services. This item amounted in 1926 to 13 percent of the total revenue receipts of the state government. Nearly half of this was collected by educational institutions and most of the remainder was accounted for by those classes of the state government receipts designated as protection of person and property, and charities, hospitals and corrections. A group of revenues designated as subventions, grants and donations accounted for 10 percent of Colorado's receipts. Almost all of this came from the federal government and nearly three-fourths of it was given for the purpose of road building. Subventions to education and agriculture made up practically all of the rest. Receipts from interest and rent made up over 6.5 percent of the total receipts of the state. This group of revenues was derived about one-third from sinking funds and two-thirds from public-trust funds. Receipts from fines, escheats and from assessments made up the remainder of the non-tax items and amounted to less than one-half of one percent of the total receipts.

An analysis of the 70 percent of the receipts of the state government coming from taxes is of more direct interest to the tax payers of the state than is the amount derived from other sources. About 37 percent of the total receipts of the state government in 1926 came from the general property tax. The gasoline tax yielded over 13.5 percent of the total. The inheritance tax contributed nearly 6 percent, the motor-vehicle license tax about 5.5 percent, business license taxes and corporation taxes for charters and on stock amounted to 6.5 percent, the greater portion of which came from the tax on insurance premiums. Fish and game licenses yielded 1.5 percent of the total.

From the point of view of agriculture, it is of interest to analyze these receipts in an effort to determine the proportion of them that is contributed directly or indirectly by farmers. It has been estimated that over one-third of the assessed value of the property of the state is farm property. It is thus proper to assign roughly 12 percent of the total state receipts to contributions from the agricultural population thru the general property tax. It has also been estimated that it is not an over-statement of the case to assign to agriculture for motor-license fees 1 percent of the total revenue receipts of the state; that is, about one-fifth of the state receipts from this

source. Farm automobiles probably use more than their proportional share of gasoline and to calculate that the gasoline-tax contribution of farmers in 1926 amounted to 3 percent of the total state revenues would not over-state the case. The agricultural contribution in the form of inheritance taxes is probably less than 1 percent of the total revenue. The total in fish and game licenses may be estimated as about the same amount.

It is difficult to determine how much farmers pay on the business taxes levied by the state. It is certain that the insurance-premium tax is passed in considerable proportion to the buyers of insurance. Possibly 1 percent more of the total revenues of the state is collected from agriculture by this means. No attempt will be made to go farther afield or to attempt to compute the amount of taxes levied on and paid by transportation companies and other public utilities which are shifted to agriculture or to estimate the increase in cost to agriculture of various articles caused by state taxation on the firms which are doing business with the farmers.

On the basis of the estimate that has been made, it is certainly under-stating the case to say that about one-fifth of the revenue of the state government is derived from agriculture. This amounted in 1926 to over three million dollars in all and to over $50 per farm. Stated in another way it amounted to about $12 per capita of farm population, or to over $16 per capita of farm population over 10 years of age.[1]

It is of interest not only to know the condition in 1926, but also to know what changes have occurred over a period of years. Table G[2] indicates the proportion of total revenue receipts of the state government that has come from each of the important sources for the fiscal years ended in 1926, 1922, 1918 and 1914. It will be noticed at once that the receipts from the general property tax amounted in 1926 to a materially smaller proportion of the total than in the previous years, particularly in 1918 and 1922. From the point of view of the owner of real estate it is possible that this means a smaller relative burden of taxation. Whether this is true depends on the source of the revenue that is replacing that formerly derived from general property.

1Farm population figures of the 1925 census of agriculture are used in making this estimate. The basis for the estimate that farm property comprises over one-third the assessed value of property in the state rests on the fact that property wholly agricultural in nature, i. e., land and improvements, livestock, tractors, and agricultural implements and machinery, accounts for over 35 percent of the assessed property. Add to this one-fifth of the value of automobiles and one-sixth of the other items not urban in nature and the percentage exceeds 37. Farm automobiles have been estimated by the **Farm Journal** as 22 percent of the total registration of the state. Farm population in 1925 was about 250,000 out of an estimated total of slightly over 1,000,000. Hence to use one sixth as the proportion of personal property belonging to the farm group seems conservative.

2See page 85.

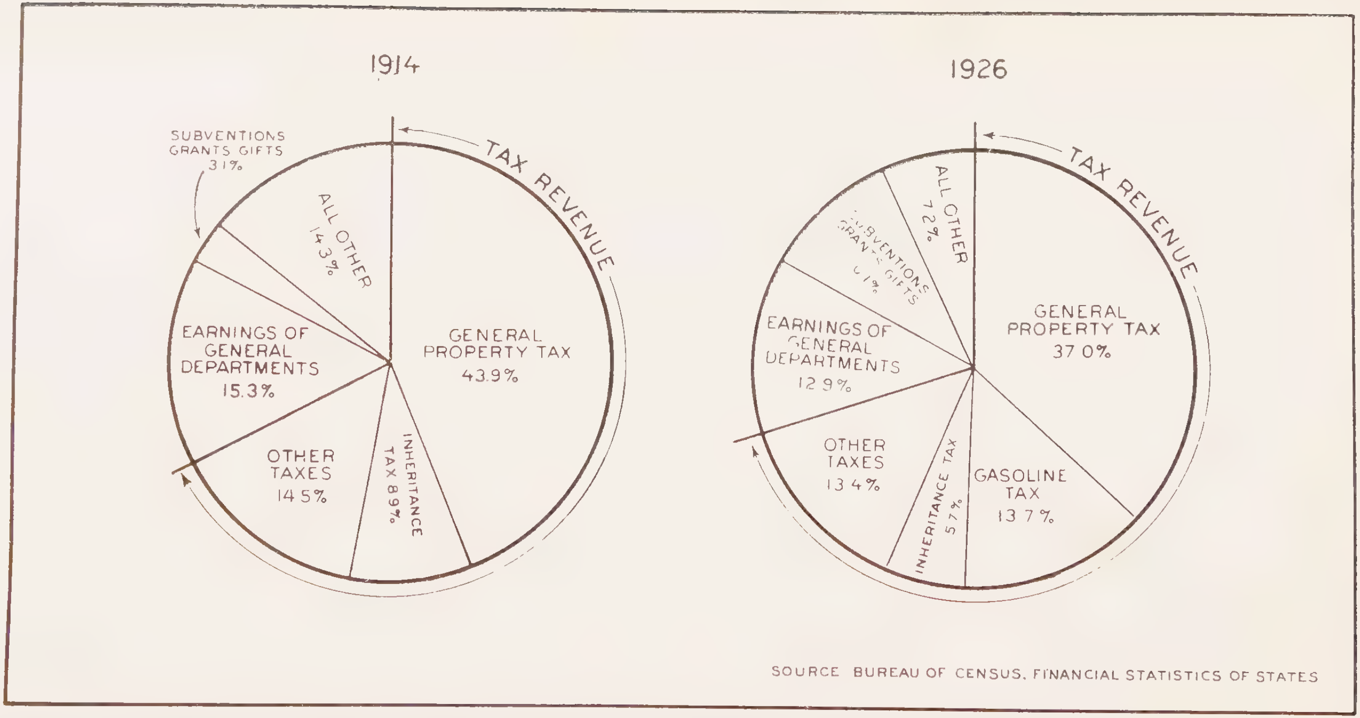

Figure 6.—Proportion of Revenue Receipts from Various Sources, State Government, Colorado, 1914 and 1926. While the percentage of tax revenue was greater in 1926 than in 1914, the percentage of revenue from the general property tax and from the inheritance tax showed a marked reduction which was more than made up by the gasoline tax.

The only other material changes in the proportion of tax revenues for the years under consideration are related to the taxation of automobiles. The gasoline tax first appeared in 1921 and in 1926 produced over one-third as much as the general property tax. Automobile-license revenues have shown an increase both in amount and in the proportion which they are of total revenue. The poll tax has disappeared as a part of the state revenue system. Business license and corporation taxes have not materially changed in their proportion to total revenue. Proceeds from the inheritance tax are necessarily erratic. In recent years they seem to have become slightly less important as a part of the state revenue than in earlier years.

In the non-tax revenue group two important changes have taken place. Rents and interest, while showing some increase in amount, have been becoming of less relative importance. Subventions, grants and gifts have materially increased in the proportion which they are of the state's revenue. This has been due almost wholly to the federal aid given for highway purposes. The proportion that non-tax revenue bore to total revenue in 1926 is only slightly different from that of 1914. The changes in the relative proportions of the various important types of revenues from that year to 1926 are illustrated by Figure 6.

The comparison of the different sources of revenue is of importance mainly from the fact that it indicates the proportion of the cost of maintaining the state government which is derived from different groups and that it may point toward the possibility of developing new sources which will relieve those made use of at present. The study of state expenditures that follows is designed to indicate the trend of expenditures for the various purposes and to furnish the basis for a critical examination of them.

EXPENDITURES OF THE STATE GOVERNMENT

Total state and local disbursements in Colorado in 1925 were reported by the state auditor as amounting to $88,543,139.96.[1]

This includes a considerable amount of duplication. For example, remittances of the state government to the counties were reported as $3,938,091 and remittances of the counties to the state government were $5,747,847. By reducing the respective amounts by these sums the total is reduced below 79 millions. Many other eliminations would be necessary in order to present a net figure for all government units of the state. Total state expenditures less amounts remitted to the counties amounted in 1925 to $13,139,474. This may

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[1] State Auditor's report 1924-26, page 59.

be estimated as less than 20 percent of the net governmental expenditures of state and local units. Emphasis is placed on this feature in order to prepare for the consideration of county and local expenditures in later sections of this chapter.

Expenditures of the state government will first be analyzed for the fiscal year 1926 and then their development will be traced thru the period 1914 to 1926. The analysis is based on material gathered by the United States Bureau of the Census and on reports of the state treasurer and auditor. In general, the census classifications will be followed as they simplify comparisons from year to year and with other states. Total expenditures are first divided into what are termed governmental-cost payments and non-governmental-cost payments. The latter group consists of book transactions which do not decrease the assets of the state and for purposes of this study need no consideration. Governmental cost payments are divided into three general groups, expenses, interest and outlays. The distinction between expenses and outlays depends on the nature of the thing for which the governmental unit spends its money. Expenses are expenditures for which no permanent or lasting possession is received by the unit concerned. They consist mainly of payments for services rendered, for property rented and for materials that are used in the maintenance of the government. Outlays include the cost of land, improvements and other acquisitions of the unit concerned which add to the number and value of its more or less permanent possessions. Interest is used in this classification with its ordinary meaning—the payment by the state of charges on debt, both funded and floating.

The total expenditures for state governmental purposes in 1926 amounted to $15,830,123. (See Table 12.) Of this 64.5 percent fell in the expense classification, 31.9 percent was classed as outlays and 3.6 percent as interest. Over 91 percent of the interest charge was on funded debt.

The expenses of general government accounted for 5.0 percent of the total. The cost of collecting revenue, the expenses of the judiciary, the maintenance of general government buildings constituted over two-thirds of these expenses of general government. If the year under discussion had been one in which the legislature had been in session, expenditures for that branch of government would have been about the same as for the three purposes just mentioned. This fact explains the alternating increase and decrease in the cost-of-government item year by year. The cost to the state of protecting persons and property was 4.6 percent of the state's expenditures. Conservation of health costs less than one percent of the total and various miscellaneous expenditures about 1.5 percent. Chief among

TABLE 12.—Governmental Cost Payments, State Government, Colorado, Selected Years, 1914-1926.

Payments	1926	1925	1924	1923	1922[1]	1920	1918[1]	1916	1914
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
All governmental costs	15,830,123	16,644,846	17,646,562	16,414,903	16,269,251	11,088,077	6,698,100	4,712,491	4,189,042
Expenses									
General government	781,274	926,138	797,949	903,618	747,346	703,724	481,111	485,662	509,875
Protection to person and property	732,611	541,599	561,494	604,325	809,997	701,265	498,017	420,192	876,160
Development and conservation, etc.	955,538	690,091	838,021	724,122	758,878	604,513	411,949	289,227	209,142
Conservation of health, etc.	129,636	151,534	143,444	139,212	136,132	124,666	53,421	46,862	42,178
Highways	1,679,991	2,623,880	2,552,989	2,194,606	1,057,397	686,885	1,174,145	551,752	321,533
Charities, hospitals and corrections	2,026,190	1,654,808	1,901,758	1,585,162	1,596,586	1,301,986	1,037,817	753,828	569,205
Education	3,646,847	3,810,936	3,413,749	3,363,776	3,180,680	2,502,267	1,776,258	1,491,874	1,203,150
Recreation	12,829	16,716	19,206	17,393	9,351	10,328	35,580	22,543	4,355
Miscellaneous	240,659	293,227	217,455	252,553	190,747	249,419	531,470	157,610	74,218
Total Expenses	10,205,575	10,708,929	10,446,065	9,784,767	8,487,114	6,885,053	5,999,768	4,219,550	3,809,816
Interest	578,273	542,154	490,318	438,737	294,034	153,017	186,923	165,692	92,133
Outlays									
General government	....	....	....	11,429	532,457	410,441	39,765	....	....
Protection to person and property	17,514	....	....	800	553,599	....	....	....	13,405
Development and conservation	150,430	54,157	17,507	60,431	35,254	23,969	....	3,963	2,364
Conservation of health	....	....	....	....	....	1,400	....	....	....
Highways	3,910,519	3,761,659	4,774,445	4,538,231	5,548,884	2,776,548	....	1,500	....
Charities, etc.	221,819	38,659	103,652	267,615	278,919	355,625	179,781	233,900	54,603
Education	704,690	1,532,915	1,807,411	1,293,514	530,964	464,039	291,863	72,508	58,916
Recreation	7,503	....	....	....	....	....	....	15,378	147,494
Miscellaneous	33,800	6,373	7,164	19,379	8,026	17,985	....	....	10,311
Total Outlays	5,046,275	5,393,763	6,710,179	6,191,399	7,488,103	4,050,007	511,409	327,249	287,093

[1]Slight adjustment necessary in order to make the total equal the sum of reported divisions of outlays.
Source: Bureau of Census, Financial Statistics of States.

the latter are costs for the maintenance of soldiers and sailors in state homes and the cost of distributing state funds and investment funds.

Three major items of the state expense—education, charities and correction and highways—deserve more detailed discussion. The amounts spent for education consist of a very small amount for supervision and the rest, 22.4 percent of the total expenditure of the state, for state educational institutions and for distribution to the local districts. The former purpose took over three-quarters of the total and the latter slightly under one-quarter of it. The amounts distributed to local districts consist of the returns from the public-school permanent fund and other receipts for the use of school land, all of which was collected and distributed by the state as an agent for the local units.

The total spent by the state for charities, hospitals and institutions of correction amounted to $2,026,190 or 12.8 percent of the total expenditures of the state. Of this 21 percent went to maintain the state charitable institutions, chiefly those for the deaf, blind and mute. Hospitals cost 47.8 percent of the total for this classification. The latter item was divided with somewhat less than 60 percent going to support institutions for the insane, 30 percent to general hospitals and a little more than 10 percent to institutions for the feeble minded. Prisons, reformatories and other institutions of correction cost $627,455 or 30.9 percent of the total placed under the charity, hospital and correction classification. This amount was almost evenly divided between institutions for adults and those for minors. A very small amount of the total, 0.3 percent, was spent for general supervision.

In 1926 the expenses of the state for the maintenance of highways was $1,679,991 or 10.6 percent of total expenditures. This particular item should not be considered without keeping in mind the fact that the major expenditure for highways is in the form of an outlay item for new construction rather than in the form of an expense item. Of the total spent for maintenance 5.8 percent went to support the supervising department, 36.8 percent to pay the costs of roads maintained by the state, and 57.4 percent in apportionments to pay the costs of the maintenance of roads by units other than the state.

Outlays made for highways, institutions of higher learning, the fish and game department, and the school for the deaf and blind, account for 95.9 percent of the total outlays made in 1926. It is to be expected that the amounts spent on the purchase of land and on the construction of buildings and other improvements will vary from

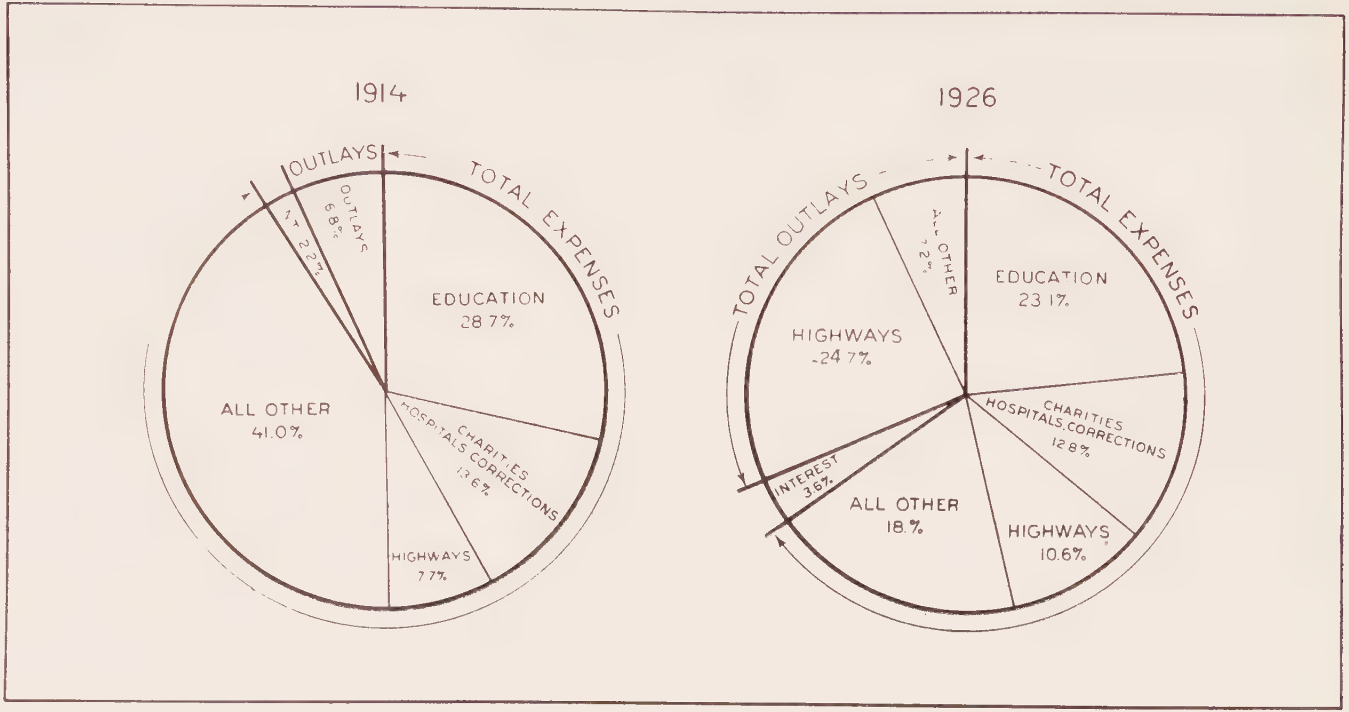


Figure 7.—Proportion of Governmental Cost Payments for Various Purposes, State Government, Colorado, 1914 and 1926. The striking difference between the two years results mainly from the growth of the outlay items.

year to year, altho the highway item will be consistently large so long as the building of an extensive state highway system is continued. If all the state educational institutions are considered, their outlay items will be fairly regular from year to year, altho any single institution may have little or no expenditures of this sort one year and large expenditures the following. The amounts spent in 1926 for the construction of highways amounted to 77.4 percent of the total outlays. Those spent for outlays by institutions of higher learning were 14.0 percent; for the fish and game department, 2.4 percent; and for the school for the deaf and blind, 2.1 percent of the total.

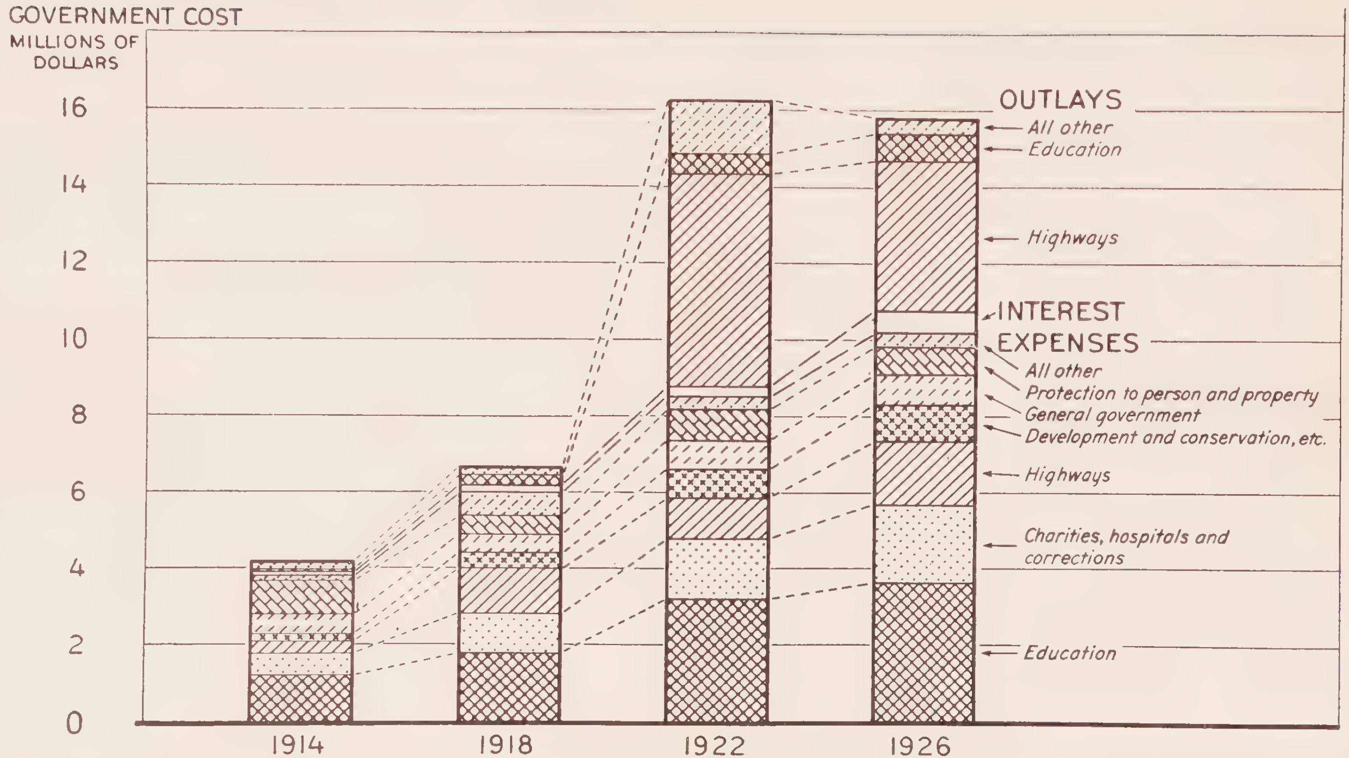
Figure 7 illustrates the way the state's expenditures were distributed among the various purposes. This is simply a summarization in graphic form of the information that has been presented in the preceding pages. It depicts the situation in 1926, and gives some indication of how the distribution of expenditure has changed since 1914 by presenting similar data for that year.

Total state expenditures have increased from $4,189,042 to $15,830,123 or 278 percent during the period from 1914 to 1926. It should be recalled, however, that the population of Colorado has increased about 17 percent and that it took approximately $1.71 in 1926 to buy the same amount that $1.00 would buy in 1914.[1]

If these two factors are taken into consideration, a real increase of slightly under 89 percent per person is estimated as the change in Colorado's state expenditures. This figure needs some qualification also, as Colorado's taxpayers in 1926 were buying thru their state taxes far different things from those which they bought with the same means in 1914. The development of a state-highway system is one illustration of this. The vastly expanded institutions of higher education furnish another. While no one will deny the need of economy in expenditures of the state and other units of government, drastic curtailment of such spending should only be made when it is certain that the proper objects of governmental expenditure will not suffer. From the point of view of agriculture, an expansion of state activity would be desirable so long as such expansion should take the form of the financing by the state of activities that are now financed by the local units. Reasons for this are fairly evident, but they will become more clear after the succeeding section of this report on local, that is county and district, receipts and expenditures has been studied.

Expenditures of the state for the years 1914, 1918, 1922 and 1926 are compared in Figure 8. This shows the increase in absolute

[1] This is based on the Snyder revised index of the general price level. The Review of Economic Statistics, Vol. X, No. 1, p. 49 (Feb. 1928).



U.S. DEPARTMENT OF AGRICULTURE

BUREAU OF AGRICULTURAL ECONOMICS

Figure 8.—Expenditures for Various Purposes, State Government, Colorado, 1914, 1918, 1922 and 1926. The large amounts of outlays, particularly of outlays for highways, in the two latter years are responsible for a considerable amount of the increase in total governmental expenditures.

amount over the period covered and also indicates how the proportions of the total devoted to the various items of expenditure have changed thru the period. It has already been shown that the money expenditures of the state have increased greatly since 1914, and that the total for 1926 was 278 percent above that for 1914. It will be of general interest to compare the increases in the various items. Expenses were 163 percent above their 1914 level, interest payments 528 percent, and outlays 1658 percent. If increases in population and changes in the purchasing power of money are taken into account it has been indicated that the real increase per capita for all expenditures was about 89 percent. The real increase of the items in the expense classification was slightly under 34 percent, of the interest payments about 314 percent, and of the outlay items about 878 percent.

Of the important expense items, development and conservation, education, highways and charities and corrections showed the greatest increases. Real expenditures per capita in the development and conservation classification, that is, expenditures adjusted for the increase in population and the decreased purchasing power of money, were about 128 percent greater in 1926 than in 1914. The major portion of this increase went for the development of agriculture. Educational expenditures in 1926, adjusted on a similar basis, were 51 percent greater than those in 1914, the greater portion of the increase going to the state educational institutions of higher learning. The real expenditures of the state for highways in 1926 were about 161 percent greater than those of 1914. The great expansion of the state's highway system during the period makes this increase a natural development. The real expenditures per capita for charities, hospitals, and institutions of correction in 1926 were about 78 percent greater than the amount spent in 1914. Large increases in this group came from expenditures for the insane and feeble minded, the maintenance of a general state hospital, non-institutional expenditures for the deaf and blind, and expenses for the institutional care of children. It is of interest to point out that the real expenditures per capita for the protection of persons and property, and for general state government were higher in 1914 than in 1926.

The outlays of the state were in 1914 confined almost wholly to three groups—recreation, education, and charities and corrections. They formed less than 7 percent of the total expenditures of that year. Outlays fluctuate within wide limits from year to year, and thus a study of the changes that use figures covering only a few years is of less value than a similar study of expenses. It is also true that the classification of outlays has been somewhat changed during the period covered.

The proportion of the total expenditures taken by the various important items has changed during the period that has been studied. This is most noticeable when the proportion between expenses and outlays is compared. In 1914 and 1918, outlays took 6.8 percent and 7.6 percent of the total, while in 1922 and 1926, this group took 46.0 percent and 31.9 percent of the total. The bulk of this change is caused by the outlays for highways, none being recorded for the earlier years, while in the two later ones such outlays took 34.1 percent and 24.7 percent of the total state expenditures.

Expenses were 90.0 percent and 89.6 percent of all expenditures in the earlier years, and were 52.2 percent and 64.5 percent in the two later ones. In view of the decreases in the proportion of the total, a similar decrease would be expected in the individual items. The status of these items, so far as the changes that have occurred since 1914 are concerned, will be seen from Table 13, which compares the percentage that each item is of the total expenses. Such a comparison makes the contrast much clearer than does the presentation in Table II, where the proportion that each item of expense bears to total expenditures is shown.

TABLE 13.—Percentage of Expenses Devoted to Various Purposes, State Government, Colorado, 1926, 1922, 1918 and 1914.

Purposes	1926	1922	1918	1914
	Percent	Percent	Percent	Percent
All Expenses	100.0	100.0	100.0	100.0
General Government	7.7	8.8	8.0	13.4
Protection of persons and property	7.2	9.5	8.3	23.0
Development and conservation, etc.	9.4	8.9	6.9	5.5
Conservation of health, etc.	1.3	1.6	0.9	1.1
Highways	16.4	12.5	19.6	8.4
Charities, hospitals and corrections	19.8	18.8	17.3	15.0
Education	35.7	37.6	29.6	31.6
Recreation	0.1	0.1	0.6	0.1
Miscellaneous	2.4	2.2	8.8	1.9

Education was the most important of the expense items in each of the years studied. Its proportion of the whole was somewhat greater in the two latest years than in the earlier ones, altho 1926 shows some decline from the highest relative point which this particular type of expenditure had reached. Charities, hospitals and corrections take, at the present time, next to the greatest proportion of total expenses. This particular class increased in each of the years under discussion, altho its total relative increase is slight. Highway expenses took only 4.8 percent of the total in 1914, rose to 19.6 percent in 1918, fell to 12.5 percent in 1922, and reached 16.4 percent in 1926. Conservation of health has shown a steady increase since 1914. Protection of persons and property and general government both took a higher proportion of expenses in 1914 than in 1926. The first of these in 1914 had its costs augmented by unusual ex-

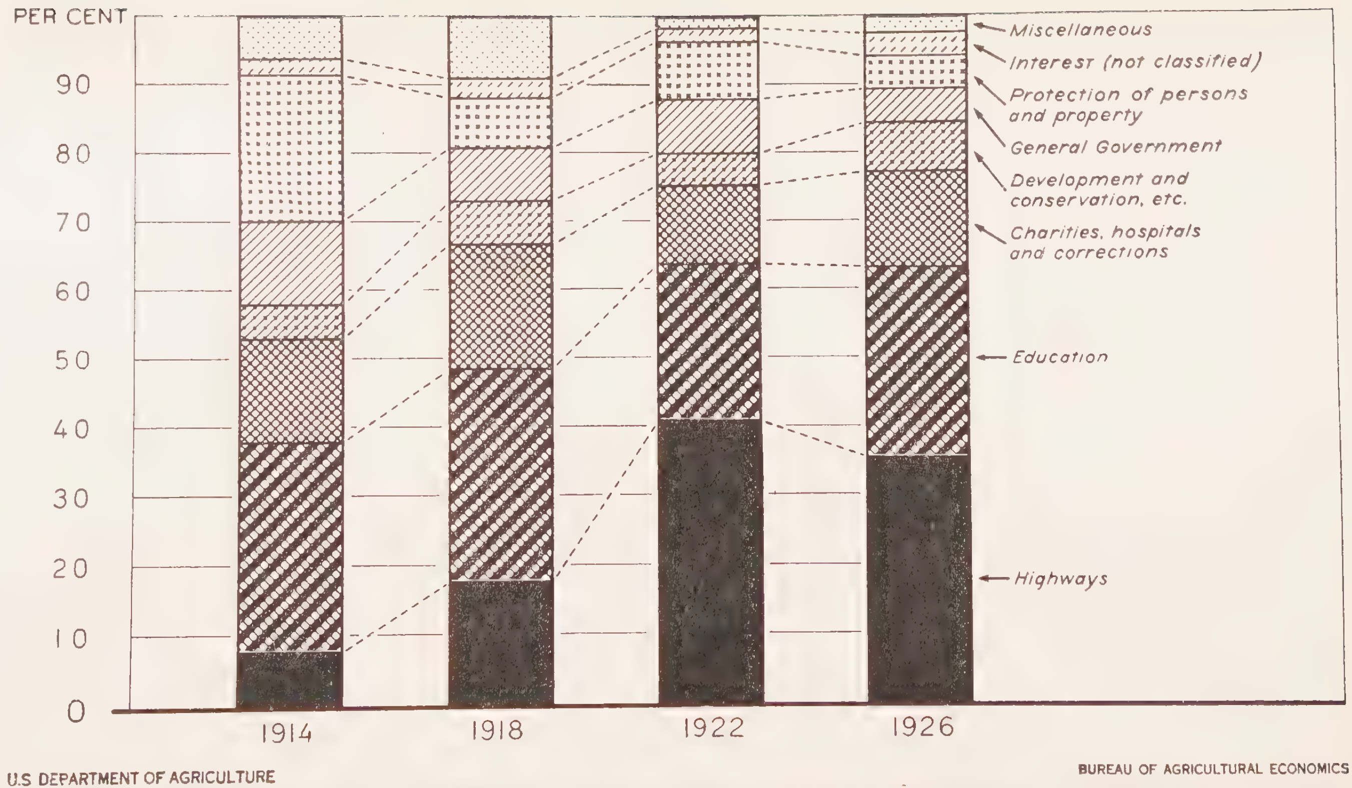


Figure 9.—Percentages of Total Expenditures Devoted to Various Purposes, State Government, Colorado, 1914, 1918, 1922 and 1926. Outlays and expenses for each year are combined and the total amounts classified on the basis of purpose. The increased percentage of total expenditures devoted to highways is most marked change of the twelve-year period.

penses for the state militia, and the second by large expenses of several groups of the executive and judicial branches. The only other item of expense large enough to need separate consideration is that classified as "miscellaneous" in 1918. It is accounted for by the expense of the various war activities of the state.

The material that has been presented should give an adequate idea of the changing emphasis of expenditures during the years that have been discussed. Figure 9 combines certain of the data that have been presented previously and illustrates the fact that over 60 percent of the state's expenditures combining expenses and outlays in 1922 and 1926, went for highways and education. If the expenditures for charities, hospitals and institutions of correction be added to these, 75 percent and 77 percent, respectively, of the total for each of the two years will have been accounted for. These items took barely more than half of the total in 1914 and about 66 percent of it in 1918. Their present importance is worth emphasizing, as they represent a type of expenditure which is of great importance to the state, and which cannot be materially reduced without great difficulty.

Local Government

It will not be possible to examine the receipts and expenditures of the local units with the detail and the exactness that have been used in the study of the state government. The basic data on which such a study must rest are not available as the county figures have not been assembled by the office of the public examiner of the state in as great detail as have the state data and it has been impossible within the limitations placed on this study to assemble any large amount of information from the individual counties. A detailed presentation of data for the counties would be impossible except in a report of great length. For these reasons, only the outstanding points relating to county and local receipts and expenditures will be mentioned here and detailed discussion of individual counties will be postponed to a later report.

Average collections per year for the five years 1921 to 1925, inclusive, reported by the treasurers of all the counties of Colorado, amounted to \$53,683,375 or to about \$54.21 per capita for these years. Of this an average annual amount of \$44,367,733 was in the form of tax collections and \$9,315,642 was classed as miscellaneous receipts. Thus 82.7 percent of the total amount collected by the counties was derived from taxes. The tax on general property was the source of practically all of this.

Before analyzing the expenditures of the counties it will be of interest to compare the total county receipts with those of the state

government. In 1925 revenue receipts of the state government amounted to $15,888,116 and the receipts of the county treasurer to $57,380,145. That is, the county receipts amounted to only a little less than four times those of the state. From the point of view of the general property tax, the difference is even more striking as the amount received by the state from general property was only $5,844,-144 while the tax collections of the counties amounted to $45,995,627. It should be noted that the difference is not quite as great as the last two figures would indicate, as the county figure includes the state levy of the general property tax and it also includes certain minor taxes other than that on general property collected by the county treasurers.

A comparison of the average tax levies in the state gives a slightly more accurate basis for this comparison. The total average levy for all units in the state in 1924 was 28.01 mills. Of this 3.70 mills went to the state, leaving the counties, towns, school districts and other local units an average levy of 24.31. It is, then, approximately accurate to state that of the total tax burden on general property, over 85 percent goes to the local units while less than 15 percent is taken by the state.

The local levy on general property is nearly six times as great as the state levy on the same property. This is emphasized in order to point out the fact that the farmer's direct tax burden is caused in large part by local collections and expenditures which are only indirectly affected by the action of the state government. If the estimate that farm property pays over one-third of the general property tax, omitting that levied for town and city purposes, is used, an average tax contribution for the year 1926, of about $54 per capita of the farming population, of $73 per capita of the farm population above 10 years, is indicated. By using the same basis for the computation, a tax contribution of nearly $235 per farm may be estimated.[1]

These figures may be combined with those on page 55 and the following estimate of total farm contribution to the state and local government units arrived at: Tax contribution per farm, about $255; per capita of farm population, $59; per capita of farm population over ten years of age, $79.

It should be pointed out that the state government has access to many sources of revenue which are not available to the local units, and if it were to take advantage of them the small contribution that is now made by the general property tax to the state government

[1] It should be noted that this estimate does not include gasoline, automobile license or other state tax apart from general property tax. The farm-population figures and the total number of farms are taken from the 1925 census figures.

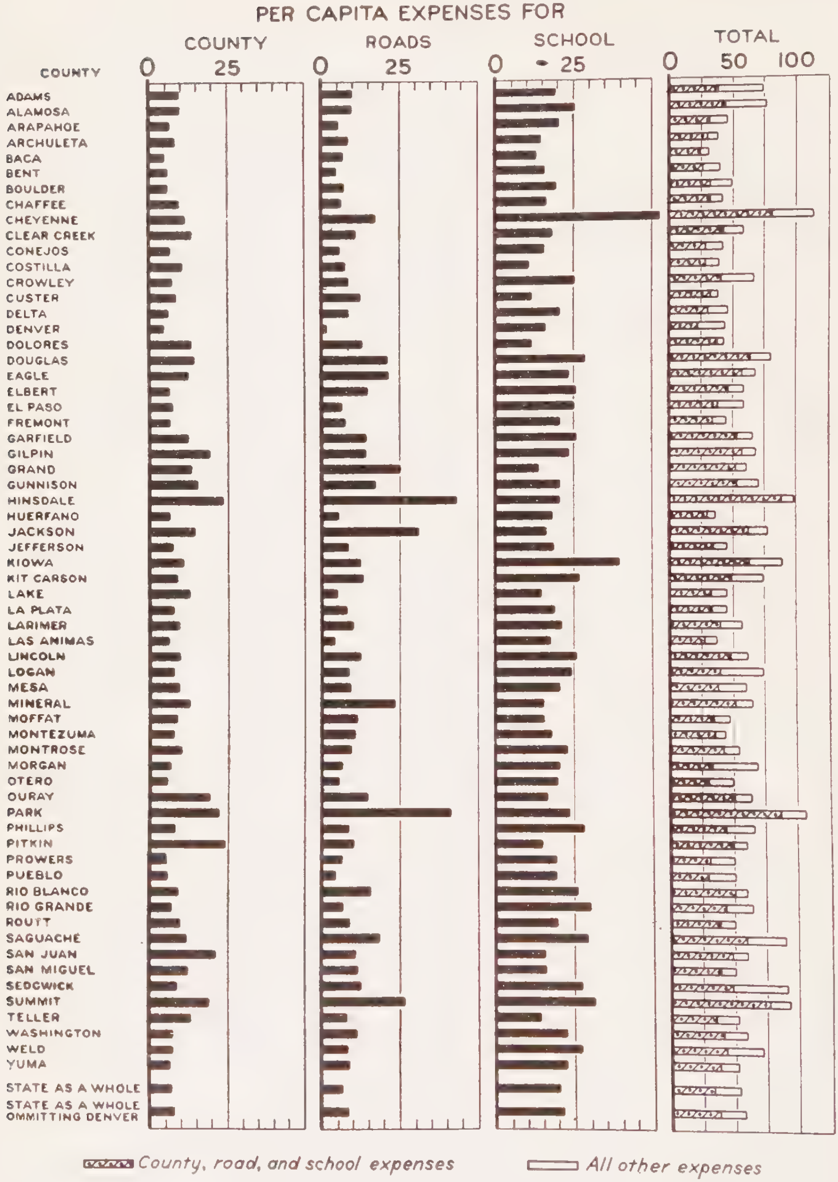
could be given up. Such possible changes, together with their relative advantages will be set forth later in this report. It is also necessary to remember that some of the local expenditures are made in accordance with the requirements of the state legislature and that no town or school district is wholly able to discontinue or, in some cases, even to decrease support of some of the activities that it is undertaking.

A most important factor to be considered in connection with local taxation is the use that is made of the money collected. It may be assumed that over a period of years all money collected in taxes or by other means will be spent. Few units will go on year after year piling up surpluses to their credit. A study of expenditure will then not only indicate what the tax money is being spent for but it will also give a fairly close idea of the amount that is being collected.

From the reports classifying disbursements of the various counties there have been computed for the years 1921 to 1925, inclusive, per capita figures for total disbursements, county expenses, road expenses and school expenses. These figures are contained in Table 14. The county-expense classification includes the general operating expenses of the county's governmental units. The other two classifications are self-explanatory. For the period covered, total per capita county disbursements averaged $53.71 per year. Of this amount $6.95 per capita were classed as county-government expenses, $6.45 as expenditures for roads and $20.22 as expenditure for schools. Expenditures by cities and irrigation districts and a small item classed as "miscellaneous" made up the total. It will be seen that school expenses took 38 percent, county government 13 percent, and roads 12 percent of the total. These three items together with that classed as "miscellaneous expense" would cover two-thirds of the total. Most of the rest was classed as city expense, with between 5 and 6 percent of the total being spent by the irrigation districts.

The presence of Denver County figures in those just quoted makes the road-expenditure item seem rather less important than it otherwise would. Omitting this county, the average per capita total becomes $57.07; county expense, $7.89; road expense, $8.38; and school expense, $21.72. This makes the percentage of the total that goes toward county government amount to 14; that spent for roads almost 15, and for schools to 38, and makes these three items amount, in all, to over two-thirds of the total.

It is natural that the per capita amounts vary among the counties altho large variations may reasonably call for some explanation. Total per capita disbursements varied from $114 per year in Cheyenne County to $31 in Baca. Figure 10 illustrates this variation and indi-



SOURCE: ESTIMATED POPULATION 1923 FROM UNITED STATES CENSUS ESTIMATES. TOTAL DISBURSEMENT FIGURES FROM THE BIENNIAL REPORT OF THE AUDITOR OF THE STATE OF COLORADO.

Figure 10.—Per Capita County and Local Disbursements by Counties, Colorado, Five-Year Average, 1921-1925. County expenses are those devoted to general governmental purposes in the counties. The school and road classifications are self explanatory. All other expenses include irrigation-district charges, city expense and a miscellaneous group which amounts to about three percent of the whole. All expense items are figured in dollars per person residing in the county in 1923.

TABLE 14.—Per Capita Disbursements by Counties of Colorado, Five-Year Average, 1921-1925.

County	Per Capita Total Disbursements	Per Capita County Expenses	Per Capita Road Expenses	Per Capita School Expenses
	Dollars	Dollars	Dollars	Dollars
Adams	74.24	9.59	9.93	19.28
Alamosa	77.01	9.74	9.89	25.29
Arapahoe	46.04	6.39	5.29	20.56
Archuleta	38.65	7.99	8.38	14.49
Baca	31.19	4.75	6.96	13.03
Bent	39.01	5.75	4.45	15.93
Boulder	49.34	5.71	7.23	19.69
Chaffee	42.60	9.54	6.05	16.62
Cheyenne	114.25	11.48	17.54	52.66
Clear Creek	58.96	13.57	10.92	18.06
Conejos	42.47	6.60	5.70	15.73
Costilla	39.51	10.41	7.52	10.56
Crowley	67.08	7.00	8.65	25.33
Custer	38.88	8.25	12.51	11.75
Delta	46.79	5.96	8.44	20.74
Denver	44.84	4.45	1.35	16.26
Dolores	43.28	13.43	13.00	11.65
Douglas	80.45	14.34	21.08	28.88
Eagle	68.27	12.50	21.59	23.74
Elbert	59.01	6.14	14.64	25.68
El Paso	59.38	7.01	6.15	25.04
Fremont	45.79	6.26	7.22	20.82
Garfield	66.41	12.31	14.16	26.76
Gilpin	68.81	19.53	14.00	23.83
Grand	61.00	13.21	25.07	13.85
Gunnison	70.43	15.21	17.30	20.60
Hinsdale	98.78	23.83	43.57	20.66
Huerfano	36.75	6.12	5.08	18.21
Jackson	77.75	14.56	31.11	16.29
Jefferson	45.77	7.20	8.21	18.80
Kiowa	89.59	10.83	12.26	39.72
Kit Carson	74 69	8.80	13.10	26.61
Lake	45.85	12.78	4.81	14.58
La Plata	45.84	7.36	7.80	19.00
Larimer	57.37	9.27	9.99	21.25
Las Animas	37.70	5.86	3.94	17.63
Lincoln	61.98	9.46	12.41	25.74
Logan	74.62	7.47	8.25	24.45
Mesa	60.61	9.05	9.00	20.67
Mineral	65.60	12.54	23.60	15.23
Moffat	47.21	8.61	11.06	15.47
Montezuma	44.06	7.34	10.68	18.06
Montrose	54.90	10.04	9.63	23.20
Morgan	69.40	6.45	6.60	20.70
Otero	49.91	5.26	5.18	20.01
Ouray	64.53	19.38	14.63	16.77
Park	107.11	22.09	41.80	23.94
Phillips	66.75	7.94	8.52	28.10
Pitkin	60.60	24.10	10.05	14.94
Prowers	50.15	5.34	6.24	19.47
Pueblo	50.99	5.56	4.11	19.31
Rio Blanco	60.85	9.03	15.66	26.02
Rio Grande	64.91	6.94	6.66	30.19
Routt	50.57	9.76	8.77	19.82
Saguache	90.44	11.81	18.52	29.31
San Juan	60.43	21.30	10.96	15.75
San Miguel	50.50	12.12	11.55	15.96
Sedgwick	92.03	8.48	12.45	27.24
Summit	93.60	19.21	26.35	31.54
Teller	52.39	13.17	7.84	14.18
Washington	59.18	7.32	11.05	22.85
Weld	72.10	7.45	8.26	27.37
Yuma	52.18	6.43	8.87	22.75
State as a whole	53.71	6.95	6.45	20.22
State as a whole omitting Denver	57.07	7.89	8.38	21.72

Source: Estimated population 1923 from United States Census estimates. Total Disbursement figures from the Biennial Report of the Auditor of the State of Colorado.

cates the proportion that each of the three principal expense items other than city expenses forms of the total. It was thought that there might be a relationship between total per capita expenses and population but a study of the figures shows that the single factor of population has no great influence on total per capita expense.

The item designated as "per capita county expense" ranges from $24.10 in Pitkin County to $4.75 in Baca County and $4.45 in Denver. In this expense item it is to be expected that the population influence will make itself felt. Not only is Denver County low but among the 24 counties in which the per capita expense was $7.50 or less, only 5 had a population below 10,000 and none had a population below 6,700. At the other extreme there were 21 counties with a per capita expense of over $10.50, no one of which had a population as high as 10,000 and only 5 of which had populations above 5,000.

Many of the items in the cost of county government must remain constant even tho the population increases materially. It is possible that by the consolidation of certain Colorado counties or by a consolidation of certain of their functions, rather marked economies might be achieved. This is a subject which calls for a more detailed investigation than can be given here.

The item of road expense per capita also shows the influence of population altho it is by no means as striking as in the case of county expenses. Of the 23 counties where the item for road expense is over $11.50 per capita none has a population of more than 9,120 and only six have populations of more than 5,000. Of 23 counties with a road expense of less than $8.50 per capita only one has less than 5,000 population and only seven, less than 10,000

This particular item of expense will be expected to show a closer relationship to the density of population than to the population itself; that is, when area and population are both taken into account there should be a more direct relation than when only one of these factors is considered. This would be particularly true in a state where there was a general uniformity in the physical features of the counties. It can be expected to follow only partially in one where certain of the counties are located in the plains and others in the high mountains. Counties in the latter location will naturally have to pay far more per mile for roads than will those of the former. In spite of this qualification it is found that each of the 15 counties with a density of population of three or less to the square mile had a per capita road expense of over $10 and that the four counties with a density of population of less than one per square mile had road-expense figures of $44, $31, $24 and $42, respectively. The effect of the density of population at the other end of the scale is not so clear

altho of the 18 counties with a population of over 10 per square mile only one, Gilpin, had a road expense of over $10 per capita. These figures should be compared with the average per capita figure for the state, omitting Denver County, for road expenses of $8.38.

The conclusions that may be drawn from a consideration of road expense are somewhat similar to those derived from the consideration of county expenses, altho the remedy will be a different one. The counties with small population and large area, particularly in those sections of the state where road building is expensive, are compelled to pay a large amount per capita for their roads. Some additional equalization from state funds should make these differences less oppressive. A detailed attempt, however, to equalize the highway expenditures of the state should not be attempted until more data, concerning the use and benefits of highways as well as abilities of people in different sections of the state to pay for them, are available. In connection with the use and benefit of highways, attention should be called to the extensive surveys recently made in certain states by their highway commissions in cooperation with the Bureau of Public Roads of the United States Department of Agriculture.

The financing of schools is to be considered in a separate report of this series and only brief attention will be given to the subject here. The per capita expense of schools varies from $10.56 in Costilla County to $39.72 in Kiowa and $52.66 in Cheyenne. Here the influence of total population seems to be of little importance. Density of population, however, has some influence in determining per capita expense, but there are many other influences which are of more importance.

It is worth while to call attention briefly to some of the inequalities among different sections of the state in their ability to support schools, altho the subject can only be suggested in this report. It will be treated at some length in a later one. Table 15 lists the total assessed valuation of the counties of the state together with their assessed valuation per school child as shown by the school census, and per pupil enrolled in school. On the census basis there is a range of assessed value per school child of from $2,356 in Conejos County to $18,030 in Park County. Considering this factor alone, Conejos County would have to apply a tax rate nearly eight times as great as that applied in Park County in order to supply the same amount to be expended for each school child. It must be admitted that assessed value and true value may be very different. It is believed, however, that in spite of certain differences among the counties that are introduced by this factor, a comparison such as is presented is not too inaccurate to be significant. Certainly Park County

assessments are not eight times as high when compared with true value as those of Conejos County.

TABLE 15.—Comparison, by Counties, of Assessed Valuations and Number of School Children, 1925-1926.

County	Total Assessed valuation	Number of school children (School census)	Assessed valuation per school child	Total number enrolled in schools	Assessed valuation per pupil enrolled
Adams	$ 31,771,520	4,865	$ 6,531	4,158	$ 7,641
Alamosa	9,346,936	2,301	4,062	2,152	4,343
Arapahoe	21,175,010	5,189	4,081	4,346	4,872
Archuleta	4,550,250	1,104	4,122	676	6,731
Baca	10,004,707	2,393	4,181	2,062	4,852
Bent	13,588,251	2,414	5,629	2,165	6,276
Boulder	47,273,532	9,545	4,953	7,552	6,260
Chaffee	10,489,660	2,051	5,114	1,578	6,647
Cheyenne	16,937,730	1,290	13,130	1,085	15,611
Clear Creek	5,424,380	596	9,101	508	10,678
Conejos	8,482,960	3,600	2,356	2,916	2,909
Costilla	5,244,260	1,774	2,956	1,319	3,976
Crowley	9,798,990	2,048	4,785	1,843	5,317
Custer	3,114,268	533	5,843	401	7,766
Delta	15,555,771	5,176	3,005	4,051	3,840
Denver	416,604,690	77,328	5,388	62,178	6,700
Dolores	1,630,444	370	4,407	249	6,548
Douglas	10,738,479	966	11,116	941	11,412
Eagle	6,522,163	854	7,637	803	8,122
Elbert	17,998,235	2,232	8,064	1,933	9,311
El Paso	70,999,530	12,315	5,765	10,471	6,781
Fremont	21,496,797	6,223	3,454	5,334	4,030
Garfield	16,760,930	2,784	6,020	2,537	6,607
Gilpin	2,636,555	267	9,875	283	9,316
Grand	4,683,230	656	7,139	573	8,173
Gunnison	15,633,235	1,614	9,686	1,334	11,719
Hinsdale	940,990	155	6,071	117	8,043
Huerfano	15,960,350	6,667	2,394	4,786	3,335
Jackson	3,677,870	301	12,219	256	14,367
Jefferson	25,711,450	5,313	4,839	4,519	5,690
Kiowa	14,353,803	1,390	10,326	1,132	12,680
Kit Carson	26,076,536	3,242	8,043	2,838	9,188
Lake	7,706,810	1,761	4,376	1,107	6,962
La Plata	15,264,755	3,958	3,857	3,109	4,910
Larimer	55,278,060	9,348	5,913	8,393	6,586
Las Animas	42,308,393	13,475	3,140	10,378	4,077
Lincoln	22,623,650	2,843	7,958	2,593	8,725
Logan	36,891,095	6,359	5,801	5,206	7,086
Mesa	29,712,195	7,944	3,740	6,846	4,340
Mineral	1,486,650	157	9,469	124	11,989
Moffat	6,572,136	1,448	4,539	1,159	5,671
Montezuma	6,296,535	2,263	2,782	2,019	3,119
Montrose	12,464,845	3,883	3,210	3,633	3,431
Morgan	28,299,506	5,830	4,854	5,415	5,226
Otero	34,495,560	6,788	5,082	6,526	5,286
Ouray	4,020,672	491	8,189	461	8,722
Park	8,510,030	472	18,030	341	24,956
Phillips	14,914,375	1,863	8,006	1,675	8,904
Pitkin	4,448,460	647	6,876	515	8,638
Prowers	21,770,175	3,951	5,510	3,770	5,775
Pueblo	74,263,765	20,691	3,589	15,249	4,870
Rio Blanco	5,291,040	918	5,764	706	7,494
Rio Grande	10,483,371	2,819	3,719	2,327	4,505
Routt	14,605,133	2,775	5,263	2,362	6,183
Saguache	11,151,184	1,942	5,742	1,425	7,825
San Juan	3,613,684	315	11,472	216	16,730
San Miguel	6,742,990	1,046	6,446	981	6,874
Sedgwick	9,985,115	1,818	5,492	1,627	6,137
Summit	4,501,909	358	12,575	299	15,057
Teller	7,004,030	1,360	5,150	1,068	6,558
Washington	23,503,472	3,660	6,422	3,241	7,252
Weld	106,102,390	18,432	5,756	16,190	6,554
Yuma	25,236,990	4,612	5,472	4,030	6,262
State	1,540,732,487	301,783	5,105	250,087	6,161

Another qualification needs to be attached to this comparison. The density of school population in Park County is much less than that in Conejos County, with the result that the costs per pupil in the latter county are below those in Park County. This difference is far from correcting the difference in ability between the counties, and the fact that there is greater expenditure in Park County arises partly from the fact that this county is able to spend more, not that it has to spend more.

It should be noted that while Park and Conejos counties are extremes, there are a number of others that illustrate very large differences in valuation per school child. Twelve counties have an assessed valuation per child of less than $4,000 and fourteen have one of over $8,000. While the average for the state is $5,105, only 27 counties out of the 63 in the state are within $1,000 of this average, i. e., between $4,105 and $6,105.

Figures computed for the assessed valuation per child enrolled in school show the same pronounced differences among the counties. So far as present expenses are concerned, this is perhaps a more important figure than the one based on the school census. The number of children enrolled in the schools of a county is a chief factor in determining its expenses of education. Hence, the total value of property in the county divided by the number enrolled in its schools will give a fair indication of the difficulties that a county may have in meeting its educational costs.

Park and Conejos counties again provide the extremes, the former having $24,956 of assessed value on which to levy taxes for each pupil enrolled, and the latter an assessed valuation of only $2,909. The average for the state as a whole is $6,161, but there is so much deviation from this average that only 23 counties are found within $1,000 of it, i. e., only 23 counties have an assessed valuation per pupil enrolled in their schools of from $5,161 to $7,161. Ten counties, Cheyenne, Clear Creek, Douglas, Gunnison, Jackson, Kiowa, Mineral, Park, San Juan and Summit have more than $10,000 of assessed value for each pupil enrolled in their schools. It should be noted that a small number of pupils rather than a large assessed value is responsible for most of these high figures. Six counties have less than $4,000—Conejos, Costilla, Delta, Huerfano, Montezuma and Montrose. While the enrollment in these counties averages higher than in the ten counties with a valuation of above $10,000 per pupil, in only Delta, Huerfano and Montrose is the enrollment as high as the average for the counties of the state, omitting Denver, so that it is safe to assume that the low average valuation cannot be entirely due to a high enrollment.

A similar lack of equality exists within many of the counties. Assessed-valuation figures for each school district have been compiled in Lincoln County and a range of from $3,322 to $40,919 per census school child was found to exist. Computed on the basis of the number of pupils enrolled, the range was from $4,319 to $52,298. While the general county school fund tends in some measure to counteract such inequalities, it can be realized that equal educational opportunity cannot be given to the children of these districts without placing exceedingly heavy burdens on the taxpayers of those districts where the assessed valuation per pupil is small. In this particular county the school levy on general property in 1927 varied among the districts from 4.49 to 23.27. It should be understood that a certain amount of this difference may come from inequalities in assessment. If it does, this is itself an indication of the need for readjustment. Even assuming something of the sort, there is left a great enough variation to call for serious thought.

When the expenditure for education is considered on the basis of per capita of county population, a wide range of costs is again revealed. For the years 1921 to 1925, Cheyenne County with a per capita expenditure of $52.66 ranked highest and Costilla County with $10.56 was lowest. It is naturally expected that where the population of a county is small the per capita contribution to education will be high. The fact that this is to be expected does not make such contribution easy for the taxpayer, particularly in those counties where the per capita wealth and income are small. Per capita expenditure in Cheyenne County was greatly in excess of the next highest county, Kiowa, which had a per capita annual expenditure of $39.72 for education over the five-year period. Two other counties, Rio Grande and Summit, spent over $30.00. At the other extreme there were eight counties in addition to Costilla which spent less than $15.00 per capita. Twenty-one counties fall in the $15.00 to $20.00 group, 16 in the $20.00 to $25.00 group, and 13 in the $25.00 to $30.00 group. The average per capita expenditure for the state as a whole over the five-year period was $20.22.[1]

There are contained in Tables I and J certain measures of economic ability which may be compared with total per capita county expenditures. Several of these measures are merely indications of such ability rather than definite statistical data. They are, however, of the most recent and definite type available and are presented with the idea that they will be of use in comparing the rela-

[1] The figures that have been quoted in this paragraph were computed from the biennial reports of the auditor of the state of Colorado. They differ slightly from the figures reported by the state superintendent of public instruction because of a different fiscal year and because of differences in methods of computation.

tive burdens placed on the inhabitants of the various counties of the state.[1]

Brief attention should be paid to certain of the data which appear in Table J. Per capita taxable wealth has been based on assessed property. It will be recognized at once that such a figure is subject to a wide margin of error. While equalization among the various counties in Colorado is perhaps as exact as in the majority of the states of the union, no one would claim that it is in any sense accurate. The per capita disbursement figure is also subject to slight qualification altho the fact that it covers a five-year period probably irons out inaccuracies which would appear if a single year had been used. It will be noticed first, that counties with a high per capita taxable wealth are in general those counties where the the per capita disbursements are high. The variation, however, between per capita taxable wealth in the wealthy and the richer and the poorer counties and per capita disbursements in these counties is by no means close. A county with 25 percent of the per capita taxable wealth of the richest counties pays out approximately 50 percent as much in per capita disbursements. Such a study might profitably be carried on in individual counties and figures presented showing that counties of almost the same per capita taxable wealth have rather large variations in their per capita disbursements, but such an analysis would require more space than is available and may profitably be made by the reader for those counties in which he is interested.

The final point to be reiterated in connection with county wealth and expenditures and which should be made with particular emphasis in the discussion of school expenditures, is that there is a large amount of inequality among counties in wealth and that expenditures are by no means equivalent to the differences in wealth. It would seem that certain of the expenditures which are now on a local or county basis should be changed to an inter-county, or possibly state-wide basis, thereby bringing a greater measure of equality among the different sections of the state.

There is the problem here that always arises when it is proposed to aid certain sections of the state at the expense of the rest. It will be argued that, if certain parts of the state have economic advantages that enable their inhabitants to secure better incomes than can be secured in other parts of the state, any attempt to counteract such advantages will have an undesirable effect on the development of the state. It must be admitted at the outset that, if it were proposed to grant any special aid to the maintenance of agriculture or to any other industry in a way that would promote the expansion of agriculture or industry in areas poorly adapted to such expansion, this

[1] See pages 86 and 87.

argument would have great weight. The suggestions that are to be made have no such intentions.

It is urged that certain waste which comes from duplications caused by the attempt to maintain units of county government in sections, where the population does not justify such government expense, be eliminated. While further study will be necessary before it can be definitely indicated where these readjustments must take place, there can be no objection to them from the point of view of encouragement of uneconomical production. Eliminations of waste governmental effort are always desirable, the only controversial points being a definition of what is waste and agreement on a method for its elimination.

The changes in methods of financing schools and roads that have been suggested may seem more open to objection. So far as roads are concerned, however, the proposal is simply that the extent to which roads are serving different groups be ascertained and where it is found that the roads are only partly local that a greater amount of state or federal support be given them. This is not subsidizing a locality or even levying taxes on the basis of ability to pay. It is simply an effort to make the larger units which benefit from the use of the roads pay for their support.

If the school question be considered on the benefit basis, several divergent lines of argument may be followed. It will be held that the local district or county benefits from good schools, as it certainly does, and that no wider unit is in any way interested. On the other hand, there are those who will argue that if a section of the state is not able to supply good schools there are many reasons from the point of view of social welfare why the whole state should be responsible for assisting that section. From another angle, it will be argued that the country is educating its children and sending many of them to the cities. Is it fair to place the whole burden, or a large part of it, on the less wealthy rural section and then give much of the results to the cities? Many people believe that the children of all the state should be given educational opportunities that are as nearly equal as possible. There certainly is no way that such equality can be given in Colorado except by the readjustment of school units and by the supplying of part of their support on a state-wide basis.

IV. RECOMMENDATIONS FOR CHANGES AND ADDITIONAL RESEARCH

The study that has been summarized in the preceding pages of this report has only covered a few aspects of the Colorado tax system. For this reason most of the recommendations to be made must be tentative in form. So far as some important features of the sys

tem are concerned, no definite recommendations can be made without a far more exhaustive examination of the results of the present system. Where this is true, the preliminary suggestions will have as their objects the indications of new lines of attack on the problem rather than a definite method by which it can be solved. The changes that may be made should have the following general objectives:

1. The broadening of the tax system so as to take advantage of sources of ability to pay taxes, which now make little or no contribution to the cost of government.

2. Altering the general property tax so as to make it fairer to all concerned.

3. Changing the method of support of various governmental activities.

4. Making possible additional economies in various governmental functions.

(1) NEW SOURCES OF TAX REVENUE.—In distributing its tax burden, Colorado uses a relatively small number of indications of ability to pay taxes. The possession and use of tangible property, including automobiles, forms a basis for collecting almost all of the tax revenue for state and local uses. Taxes on an insignificant amount of intangible property, levies on inheritance and business and other so-called license taxes, account for all that is collected from other sources. Thus, much Colorado wealth makes no direct contribution to the support of state and local government.

Two outstanding methods of broadening the tax system suggest themselves. Intangible property might be made to pay some part of the cost of government. Income might be used as a basis for a part of the tax system. Each of these will be considered in turn.

In a number of states it has been found possible to collect a considerable amount of revenue from intangible property by taxing it at a lower rate than tangible property. When only a small portion of the income of such property is taken by taxes, it has been found that some of the owners are willing to report it to the assessors and a fair amount of it contributes to the revenue system. A tax of 50 cents on a hundred dollars of market value would take on the average only about 10 percent of the income of intangibles. The tax payer who owns such property should appreciate the fairness of this tax as compared with the present tax which, if it were applied according to the letter of the law, would take from 30 to 60 percent of such income. Even under such a change it will be difficult to secure a satisfactory adjustment of this problem without many changes in

administration, but the state should consider making a start by classifying intangible property and taxing it at a low rate.

An income tax is no longer an experiment. The federal government collects a vast amount of revenue by such means. Twelve states tax individuals on the basis of income. Such a tax, properly administered, will bring a fair amount of revenue into the public treasury and will secure some of this revenue from many who at present make slight or no direct contributions to the support of government. Too much, however, should not be expected from an income tax in Colorado. At rates which would be politically practicable, it is doubtful whether in the early years of the tax more than $2,000,000 or $2,500,000 could be raised. While such an amount is by no means to be despised, it needs to be recalled that if it all should be applied to the reduction of the state levy on general property it would reduce that by less than 50 percent. In 1924 the state levy on general property averaged only about 13 percent of the total levy. In other words, the income tax might make possible a reduction of from 5 to 6 percent of the levy on general property. This assumes that it would all be applied to this purpose.

In spite of the fact that a state income tax cannot be made to yield a large enough sum to reduce materially the burden on general property, it is felt that its introduction would be decidedly worth while. Income is generally acknowledged to be the fairest basis for taxation. Many incomes represent tax-paying ability that is not at present directly touched by existing taxes. The addition of an income tax will broaden the tax base of the state and will be of some assistance to those groups in the state which are now most heavily burdened.

ALTERATIONS IN THE GENERAL PROPERTY TAX. — The first method of broadening the tax base, namely, the classification of property for tax purposes and the use of a lower rate on intangibles, involves a change in the general property tax. It has been discussed above and needs no further mention here.

Other changes in the general property tax involve either changes in principle or in administration. Desirable changes of the latter sort have to do mainly with the methods of applying the present assessment system and have been discussed in detail earlier in this report.

It has been urged by some that the whole basis of assessment as practiced at present is wrong and that the principles of the system need changing. The use of a so-called sales-value figure as the measure of the tax-paying liability of a piece of property has been widely

criticised. While it is felt that much of this criticism is correct, it is believed that the direction which change ought to take has not been charted definitely enough to make a recommendation on the subject possible. More research toward the discovery of equitable assessment principles seems badly needed. It is believed that there may be a possibility of working out a system which will make some closer reflection of the income-yielding ability of property than sales value the measure of taxpaying liability. Such a system has not yet been accurately outlined or tested. Until it has been and until some assurance has been given that it will work, no definite recommendations for change in this direction can be made.

(3) CHANGING UNITS OF SUPPORT.—It has been suggested at various stages of this report that certain activities of government could be carried on more economically and more equitably if the governmental units maintaining them were to be altered. Roads and schools form excellent illustrations of the possibilities in this direction. A wider use of state funds and supervision in the construction and maintenance of roads is certainly justified by the use to which roads are put. Such a change should make possible economies in planning and in actual work. The responsibility of the state toward the education of its children will be denied by few. The fact that without state assistance there can be no such thing as equality of educational opportunity is not open to doubt. The extent of the inequalities that exist and the methods of removing them need more study than they have thus far been given, altho the details rather than the principles involved need clarification.

(4) ECONOMIES IN GOVERNMENTAL FUNCTIONS.—This subject is suggested here mainly as a field for further study. No one doubts that there is opportunity for a reduction in many of the costs of government without curtailing the services that the government supplies to its people. Duplications caused by county governments which were planned in the day of the horse and wagon rather than the motor car and inefficiency arising from the maintenance of an excessive number of small school units are typical of many that might be cited. Analysis of fiscal conditions in typical taxing districts of all sorts and sizes in many sections of the state need to be made, and on the basis of such studies general plans for more efficiently supplying the services that the government must furnish the people may be suggested.

Progress in this direction need not wait, however, for adoption of general plans. A study of counties or even of school districts will reveal opportunities for better buying, for consolidation of functions, or for the lopping off of unnecessary extravagances. Such studies would be designed (1) to ascertain if waste, particularly preventable

waste, exists in the unit examined, and (2) to indicate methods by which such waste can be reduced. They would examine the expenditures to see, not only how much was being spent, but also what was being received by the taxpayers in return for their expenditures. Unit costs for various services could be compared with costs in similarly situated communities.

The planning of receipts and expenditures on the basis of approved budgetary methods should certainly form part of the study in any section where such methods are not in use. Such planning, by itself, will often open the way to saving.

It should, however, be emphasized that analyses of the sort mentioned need to be directed by individuals trained in such work. It is only by such expert direction that results of value can be expected. It is also urged that the cooperation of the governmental officials of units concerned be secured and be used. Thru their help much misdirected energy can be eliminated. Their natural suspicion will be largely avoided, if they understand the purposes and methods of the studies.

Efficient economy in public expenditures can only come when the work of the governmental units has been so analyzed that it is possible to determine whether money is being effectively used for the greatest public good. Such analysis, however, is but one step toward the desired result. Public opinion must be so educated that it will demand that the results of studies be applied to the every-day work of the governmental units.

The process here is really a twofold one. Research can bring certain possibilities to the attention of the general public. Then the people, convinced that the economies are practicable, can urge public officials to adopt them. Thus research in public expenditure has not only the responsibility of discovering the facts, but must also place these facts before the people in such a way that they can effectively demand that the standards of collective consumption be raised and that new economies be used in public business.

TABLE A.—General Property Taxes and Net Rent of Farms in Five Agricultural Districts of Colorado, 1919, 1923, 1925 and 1926.

District	Year	Number of Farms	Acres	Net Rent Per Acre (before deducting taxes)	Taxes Per Acre	Relation of Taxes to Net Rent
		Number	Number	Dollars	Dollars	Percent
Northern Colorado	1919	76	19,891	3.71	1.18	31.8
	1923	116	29,796	2.93	1.16	39.6
	1925	161	41,934	2.72	1.00	36.6
	1926	91	25,637	3.50	.89	25.6
Plains	1919	124	50,669	1.40	.28	20.4
	1923	171	62,662	.96	.36	36.9
	1925	229	92,299	.91	.32	35.6
	1926	113	50,293	.63	.34	53.9
Western Slope	1919	17	1,697	6.10	1.11	18.2
	1923	31	3,811	4.09	1.54	37.5
	1925	43	5.531	8.27	1.51	18.2
	1926	27	2,327	6.17	1.98	32.0
Arkansas Valley	1919	28	5,438	9.11	1.59	17.4
	1923	37	9,873	3.48	1.28	36.8
	1925	51	12,225	3.62	1.28	35.2
	1926	26	5,482	3.89	1.17	30.0
Southeastern Colorado	1919	9	4,530	2.13	.22	10.4
	1923	22	10,921	1.13	.20	17.2
	1925	32	16,486	.79	.19	24.3
	1926	15	5,884	.31	.17	54.5

TABLE B.—Taxes and Profits of Privately Owned Electric, Gas, Water and Telephone Utilities, Colorado, 1922 and 1923.

Type of utility	Year	Number reporting	Total revenues	Net profit from operation before deducting taxes	Taxes accrued	Percentage of net profit taken by taxes
			Dollars	Dollars	Dollars	Percent
Electric	1922	55	6,422,253.14	2,592,950.04	637,600.83	24.6
	1923	54	9,489,860.75	4,452,432.06	761,929.19	17.1
Gas	1922	8	857,263.96	175,714.25	53,556.72	30.5
	1923	9	2,523,568.74	421,475.08	228,473.52	54.2
Water	1922	21	200,958.58	83,795.64	29,938.21	35.7
	1923	22	199,561.40	73,786.95	28,093.95	38.1
Telephone	1922	56	6,128,922.12	1,633,220.39	641,001.59	39.2
	1923	61	6,341,020.50	1,749,960.36	666,552.71	38.1
All reporting	1922	140	13,609,397.80	4,485,680.32	1,362,097.35	30.4
	1923	146	18,554,011.39	6,697,654.45	1,685,049.37	25.2

Source: Tenth and Eleventh Annual Reports of the Public Utilities Commission of the State of Colorado.

TABLE C.—Taxes and Incomes of National Banks, Colorado, 1919-1926.

Year ending June 30	Number of banks	Total gross earnings	Taxes	Total other expenses	Net earnings (before deducting taxes)[1]	Ratio of taxes to net earnings (before deducting taxes)[1]	Net additions to profits (before deducting taxes)	Ratio of taxes to net additions to profit (before deducting taxes)
1926		Dollars[2]	Dollars[2]	Dollars[2]	Dollars[2]	Percent	Dollars[2]	Percent
Colorado	119	5,959	484	4,032	1,927	25.1	666	72.7
Denver	6	7,283	381	4,980	2,303	16.5	1,203	31.7
Pueblo	2	861	94	526	335	28.1	221	42.5
1925								
Colorado	126	6,021	534	4,204	1,817	29.4	819	65.2
Denver	9	7,223	398	5,153	2,070	19.2	1,267	31.4
Pueblo	2	784	97	462	322	30.1	322	30.1
1924								
Colorado	130	6,103	586	4,299	1,804	32.5	692	84.7
Denver	9	7,992	296	4,977	3,015	9.8	1,869	15.8
Pueblo	2	737	92	391	346	26.6	175	52.6
1923								
Colorado	132	6,229	621	4,297	1,932	32.1	797	77.9
Denver	9	5,796	362	4,328	1,468	24.7	1,195	30.3
Pueblo	2	772	89	360	412	21.6	347	25.6
1922								
Colorado	133	6,562	661	4,436	2,126	31.1	965	68.5
Denver	8	5,508	292	3,816	1,692	17.3	931	31.4
Pueblo	2	755	80	353	403	19.9	110	72.7
1921								
Colorado	133	7,297	756	4,782	2,515	30.1	1,597	47.3
Denver	8	5,981	361	4,327	1,654	21.8	825	43.8
Pueblo	2	1,022	77	372	650	11.8	404	19.1
1920								
Colorado	131	6,936	699	4,042	2,894	24.2	2,518	27.8
Denver	8	5,428	271	3,673	1,755	15.4	1,427	19.0
Pueblo	2	787	78	330	457	17.1	408	19.1
1919								
Colorado	120	5,963	530	3,338	2,625	20.2	2,394	22.1
Denver	5	4,441	314	2,909	1,532	20.5	1,454	21.6
Pueblo	2	850	64	315	535	12.0	495	12.0

Source—Annual report of the Comptroller of Currency. [1] Not including losses charged off or recoveries on charged off assets. [2] 000 omitted.

TABLE D.—Number of Corporations Reporting Net Income and No Net Income, Colorado, 1919-1925.

Year	Total number of corporations	Reporting net income		Active corporations reporting no net income		Inactive corporations reporting no net income	
		Number	Percentage of total	Number	Percentage of total	Number	Percentage of total
1919	6,704	3,107	46.35	3,597	53.65	........[1]	....
1920	6,812	2,976	43.69	3,836	56.31	........[1]	....
1921	6,559	2,340	35.68	3,043	46.39	1,176	17.93
1922	6,855	2,720	39.68	2,784	40.61	1,351	19.71
1923	6,344	2,636	41.55	2,936	46.28	772	12.17
1924	6,494	2,891	44.52	3,043	46.86	560	8.62
1925	6,399	2,983	46.62	3,242	50.66	174[1]	2.72

Data from Statistics of Income, 1919-1925. United States Bureau of Internal Revenue.

[1] Inactive corporations are not reported separately for 1919 and 1920. They are included in the total number of active corporations reporting no income. In 1925 only inactive corporations, the businesses of which are not given, are included in the inactive column. Other inactive corporations are included with the active corporations reporting no incomes.

TABLE E.—Number of Active Corporations Reporting Net Income and No. Net Income, by Industrial Groups, Colorado, 1923-1925.

Industrial Groups	1923				1924				1925			
	Total Number	Number reporting Net income	Number reporting No net income	Percentage reporting net income	Total Number	Number reporting Net income	Number reporting No net income	Percentage reporting net income	Total Number [1]	Number reporting Net income	Number reporting No net income	Percentage reporting net income [1]
Agriculture and related industries	284	83	201	29.23	289	101	188	34.95	284	118	166	41.55
Mining and Quarrying	1.003	168	835	16.75	1,152	173	979	15.02	1,176	203	973	17.26
Manufacturing	620	333	287	53.71	663	383	280	57.77	687	368	319	53.57
Construction	89	48	41	53.93	87	55	32	63.22	91	55	36	60.44
Transportation and other public utilities	227	111	116	48.90	226	120	106	53.10	251	128	123	51.00
Trade	1,410	857	553	60.78	1,505	945	560	62.79	1,501	990	511	65.96
Professional, amusements, hotels, etc.	407	244	163	59.95	423	253	170	59.81	433	243	190	56.12
Banking insurance and related business	1,459	759	700	52.02	1,537	839	698	54.59	1,663	849	814	51.05
Combinations not classifiable	73	33	40	45.21	52	22	30	42.31	139	29	110	20.86
Total active corporations	5,572	2636	2936	47.31	5,934	2,891	3,043	48.72	6,225	2,983	3,242	47.92

[1] A small number of the corporations reported in these columns are inactive. Their inclusion makes only a slight difference in the percentage figures.

TABLE F.—Assessed Valuation of Different Classes of Property in Colorado, 1912, 1913, 1918-1925.[1]

Class of Property	1912	1913	1918	1919	1920	1921	1922	1923	1924	1925
Lands and Improvements	$ 89,859,390	$ 322,857,915	$ 406,347,182	$ 466,583,588	$ 526,272,869	$ 549,976,126	$ 532,266,343	$ 520,933,429	$ 511,776,827	$ 496,376,523
Metalliferous Mining Properties	18,012,830	46,042,067	33,594,911	29,685,516	27,219,015	24,743,817	24,276,640	23,892,866	23,131,714	23,081,307
Livestock	18,003,589	63,562,749	114,622,555	114,571,936	102,792,539	68,921,431	62,821,752	55,768,000	48,865,168	47,022,156
Timber, Coal and Oil Properties	8,361,310	20,521,089	26,428,917	24,814,574	24,359,580	25,437,444	21,954,776	24,403,825	26,197,239	28,676,909
Town and City Lots and Improvements	168,962,868	465,142,407	381,243,444	385,779,834	407,973,980	418,796,295	429,160,986	446,300,599	460,128,381	478,594,338
Corporations Assessed by Tax Commission	61,013,179	260,241,995	245,656,740	231,777,130	227,454,190	226,418,960	226,126,970	227,966,480	227,770,150	227,387,440
Merchandise	16,691,083	48,103,599	79,846,131	92,371,171	92,129,113	87,361,814	79,842,423	79,833,310	80,241,963	81,055,785
Capital Employed in Manufactures	3,507,675	13,575,571	29,341,520	31,936,595	39,428,674	41,037,125	38,705,447	37,350,254	39,702,880	38,336,462
Bank Stock	7,793,696	28,924,765	24,141,920	25,719,639	28,916,377	31,001,533	29,850,523	29,783,653	25,821,158	24,951,673
Money, Credits and Accounts	4,080,359	11,193,326	61,172,322	66,181,308	68,017,400	19,588,307	18,705,414	18,303,246	19,872,634	17,791,837
Miscellaneous (less exemptions)	26,156,100	26,481,947	19,717,633	25,792,368	45,703,930	84,973,647	84,906,605	78,676,230	74,588,606	77,458,057
Totals	$422,442,079	$1,306,647,430	$1,422,113,275	$1,495,213,659	$1,590,267,667	$1,578,256,499	$1,548,617,879	$1,543,211,892	$1,538,096,720	$1,540,732,487

[1] Annual reports of the Colorado Tax Commission.

TABLE G.—Percentage of Revenue Receipts from Various Sources, State Government, 1926, 1922, 1918 and 1914.

Source	1926	1922	1918	1914
	Percentage	Percentage	Percentage	Percentage
General Property Tax	37.0	47.4	55.7	43.9
Corporation Stock Tax	1.2	1.3	2.9	1.1
Poll Tax	.....	0.2	1.7	2.4
Inheritance Tax	5.7	3.7	4.3	8.9
Corporation Filing Tax	0.6	0.8	0.7	.....
Business Taxes	4.7	3.7	4.8	6.4
Gasoline Tax	13.7	2.5	.....	.....
Fish and Game Licenses	1.5	1.2	1.2	3.3
Motor Vehicle Licenses	5.4	3.8	2.6	.....
Permits	*	0.1	0.1	1.3
Total Tax Revenues	69.8	64.7	74.0	67.3
Assessments for Highway Uukeep	.....	.....	.....	.....
Assessments for Highway Outlay	0.4	4.0	.....	.....
Fines and Escheats	*	0.2	0.1	0.5
Subventions, Grants and Gifts	10.1	11.6	2.2	3.1
Rents and Interest	6.8	7.1	10.9	13.8
Earnings of General Departments	12.9	12.4	12.8	15.3
Total Revenue Receipts	100.0	100.0	100.0	100.0

Computed from Financial Statistics of States, U. S. Bureau of Census.
*Less than 0.05 percent.

TABLE H.—Percentage of Governmental Cost Payments of the State Government Devoted to Various Purposes, 1926, 1922, 1918 and 1914.

Purpose	1926	1922	1918	1914
	Percentage	Percentage	Percentage	Percentage
All governmental costs	100.0	100.0	100.0	100.0
Expenses - Total	64.5	52.2	89.6	91.0
General Government	5.0	4.6	7.2	12.2
Protection of persons and property	4.6	5.0	7.5	20.9
Development and conservation, etc.	6.0	4.7	6.2	5.0
Conservation of health, etc.	0.8	0.8	0.8	1.0
Highways	10.6	6.5	17.5	7.7
Charities, hospitals and corrections	12.8	9.8	15.5	13.6
Education	23.1	19.5	26.5	28.7
Recreation	0.1	0.1	0.5	0.1
Miscellaneous	1.5	1.2	7.9	1.8
Interest	3.6	1.8	2.8	2.2
Outlays - Total	31.9	46.0	7.6	6.8
General Government	.....	3.3	0.6	.....
Protection of persons and property	0.1	3.4	.....	0.3
Development and conservation, etc.	1.0	0.2	.....	0.1
Conservation of health, etc.	.....	.....	.....	.....
Highways	24.7	34.1		.....
Charities, Hospitals and corrections	1.4	1.7	2.7	1.3
Education	4.5	3.3	4.3	1.4
Recreation	*	.....	.....	3.5
Miscellaneous	0.2	*	.....	0.2

Computed from Financial Statistics of States, U. S. Bureau of Census.
*Less than 0.05 percent.

TABLE I.—Density of Population, 1924.

County	Estimated Population 1924	Area in Square Miles	Density of Population Per Square Mile
Adams	16,939	1,262	13.4
Alamosa	5,376	727	7.4
Arapahoe	15,353	842	18.2
Archuleta	3,720	1,220	3.0
Baca	11,534	2,552	4.5
Bent	11,818	1,524	7.8
Boulder	32,555	764	42.6
Chaffee	7,811	1,083	7.2
Cheyenne	3,773	1,777	2.1
Clear Creek	2,891	390	7.4
Conejos	8,788	1,252	7.0
Costilla	5,253	1,185	4.4
Crowley	7,262	808	9.0
Custer	2,274	747	3.0
Delta	13,668	1,201	11.4
Denver	276,027	58	4759.1
Dolores	1,516	1,043	1.5
Douglas	3,663	845	4.3
Eagle	3,567	1,620	2.2
Elbert	7,728	1,857	4.2
El Paso	44,346	2,121	20.9
Fremont	17,883	1,557	11.5
Garfield	9,304	3,107	3.0
Gilpin	1,364	132	10.3
Grand	3,021	1,866	1.6
Gunnison	5,590	3,179	1.8
Hinsdale	538	971	.6
Huerfano	18,491	1,500	12.3
Jackson	1,488	1,632	.9
Jefferson	14,476	808	17.9
Kiowa	4,143	1,798	2.3
Kit Carson	9,563	2,159	4.4
Lake	6,630	371	17.9
La Plata	11,402	1,851	6.2
Larimer	29,052	2,629	11.1
Las Animas	41,392	4,809	8.6
Lincoln	9,339	2,570	3.6
Logan	22,449	1,822	12.3
Mesa	22,318	3,163	7.1
Mineral	779	866	.9
Moffat	6,206	4,658	1.3
Montezuma	6,817	2,051	3.3
Montrose	12,558	2,264	5.5
Morgan	19,090	1,286	14.8
Otero	25,735	1,259	20.4
Ouray	2,620	519	5.0
Park	1,977	2,242	.9
Phillips	6,549	688	9.5
Pitkin	2,707	1,019	2.7
Prowers	15,803	1,630	9.7
Pueblo	60,092	2,433	24.7
Rio Blanco	3,497	3,223	1.1
Rio Grande	8,441	898	9.4
Routt	10,824	2,309	4.7
Saguache	4,854	3,133	1.5
San Juan	1,700	453	3.8
San Miguel	5,544	1,288	4.3
Sedgwick	4,727	531	8.9
Summit	1,724	649	2.7
Teller	6,696	547	12.2
Washington	13,566	2,521	5.4
Weld	60,803	4,022	15.1
Yuma	16,343	2,367	6.9
State	1,003,355	103,658	9.7

Sources: Population estimated from United States Census Reports.
Area in square miles from Colorado Yearbook, 1926.

TABLE J.—Measures of Per Capita Economic Ability and Expenditures by Counties.

County	Per Capita Value added by Manufacturers	Per Capita Value of Gold, Silver, Lead, Copper and Zinc	Per Capita Value of Coal and Petroleum	Per Capita Value of Crops	Per Capita Taxable Wealth	Per Capita Disbursements (Average 1921-25)	Ratio of Expenditures to taxable wealth
Adams	176	*	......	232	1,893	74.24	3.92
Alamosa	24	......	......	203	1,723	77.01	4.47
Arapahoe	36	......	......	141	1,387	46.04	3.32
Archuleta	71	......	12	95	1,238	38.65	3.12
Baca	5	......	......	149	842	31.19	3.70
Bent	9	......	......	187	1,143	39.01	3.41
Boulder	130	1	57	90	1,436	49.34	3.44
Chaffee	126	4	......	67	1,356	42.60	3.14
Cheyenne	2	......	......	354	4,851	114.25	2.36
Clear Creek	21	37	......	9	1,899	58.96	3.11
Conejos	69	......	......	200	960	42.47	4.43
Costilla	15	......	......	109	1,028	39.51	3.84
Crowley	74	......	......	296	1,351	67.08	4.97
Custer	5	83	......	236	1,362	38.88	2.85
Delta	9	......	18	250	1,203	46.79	3.89
Denver	180	......	......	......	1,468	44.84	3.06
Dolores	5	16	......	70	1,029	43.28	4.20
Douglas	208	......	......	165	3,062	80.45	2.63
Eagle	7	516	......	245	1,790	68.27	3.81
Elbert	1	......	1	222	2,363	59.01	2.50
El Paso	50	......	22	48	1,593	59.38	3.73
Fremont	191	......	154	72	1,201	45.79	3.81
Garfield	13	......	7	239	1,803	66.41	3.68
Gilpin	16	49	......	13	2,076	68.81	3.32
Grand	282	......	......	26	1,502	61.00	4.06
Gunnison	23	101	272	154	2,836	70.43	2.48
Hinsdale	12	55	......	124	1,721	98.78	5.74
Huerfano	7	......	376	27	873	36.75	4.21
Jackson	56	......	30	1,309	2,585	77.75	3.01
Jefferson	26	......	19	140	1,706	45.77	2.68
Kiowa	5	......	......	205	3,418	89.59	2.62
Kit Carson	10	......	......	404	2,727	74.69	2.74
Lake	161	410	......	13	1,168	45.85	3.93
La Plata	63	3	25	118	1,323	45.84	3.46
Larimer	208	......	3	163	1,916	57.37	2.99
Las Animas	41	......	238	27	1,037	37.70	3.63
Lincoln	12	......	......	304	2,478	61.98	2.50
Logan	64	......	......	296	1,697	74.62	4.40
Mesa	49	......	15	196	1,319	60.61	4.59
Mineral	8	231	......	109	1,893	65.60	3.47
Moffat	4	......	47	109	988	47.21	4.78
Montezuma	16	......	3	169	898	44.06	4.91
Montrose	23	*	4	294	1,033	54.90	5.31
Morgan	127	......	......	236	1,500	69.40	4.63
Otero	149	......	......	170	1,309	49.91	3.81
Ouray	21	73	......	127	1,576	64.53	4.09
Park	46	83	......	510	4,290	107.11	2.50
Phillips	16	......	......	497	2,429	66.75	2.75
Pitkin	7	54	16	162	1,685	60.60	3.60
Prowers	45	......	......	226	1,447	50.15	3.47
Pueblo	241	......	......	43	1,222	50.99	4.17
Rio Blanco	17	......	3	201	1,405	60.85	4.33
Rio Grande	24	*	......	324	1,268	64.91	5.12
Routt	34	......	288	153	1,335	50.57	3.79
Saguache	22	4	......	473	2,324	90.44	3.89
San Juan	9	2,132	......	......	1,940	60.43	3.12
San Miguel	20	535	......	52	1,286	50.50	3.93
Sedgwick	5	......	......	577	2,194	92.03	4.19
Summit	4	424	......	79	2,624	93.60	3.57
Teller	21	741	......	42	1,025	52.39	5.11
Washington	4	......	......	397	1,906	59.18	3.10
Weld	62	......	59	290	1,814	72.10	3.97
Yuma	7	......	......	419	1,528	52.18	3.41
State	107	19	32	132	1,378	53.71	3.90

*Less than $0.50 per capita.

Sources: Value added by manufacturers from Census of Manufactures 1919. Value of Gold, Silver, Copper, Lead and Zinc, Coal and Petroleum from Mineral Resources of the United States 1924. (Average price of petroleum taken as $1.10 per bbl.) Value of crops from Colorado Yearbook, 1926. (This does not include livestock and livestock products.)

Bulletin 347 May, 1929

CARBON DISULFIDE FOR THE ERADICATION OF PERENNIAL WEEDS

CHARLES F. ROGERS

and

IRA HATFIELD

A Progress Report

COLORADO EXPERIMENT STATION
COLORADO AGRICULTURAL COLLEGE
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SUMMARY

1. Weeds are causing millions of dollars of loss every year to Colorado farmers. A large part of this loss, which can be stopped by the proper control and eradication methods, is due to noxious perennial weeds. The root systems of perennial weeds must be killed if eradication is to be effected.

2. Eradication of perennial weeds with a single treatment is highly desirable.

3. Sprays have not yet proved to be a promising means of weed eradication in Colorado because their penetration is not as great in the dry climate of this state as in more humid regions.

4. Carbon disulfide injected into the soil has been used successfully to eradicate perennial weeds with a single treatment. It can be applied at times when there will be no loss of a crop. The method of application is described in this bulletin.

5. The poisonous effect of carbon disulfide upon the soil is temporary. After a few weeks the productiveness of the soil is increased.

6. The test plots of 1927 were established upon many kinds and under many conditions of soil. There was a 90 to 100 percent kill on four-fifths of them, and at least a 60 percent kill on the remainder.

7. In a number of cases the killing of the perennial weeds with carbon disulfide was not noticeable for several months, but the final results were as good as tho the killing had been immediately apparent.

8. The use of carbon disulfide has formerly been attended with uncertainty both as to the rate and the amount of killing when the liquid was injected into the soil. In 1928 a chemical was found which would indicate the presence of carbon disulfide and which could be used to test the penetration of carbon disulfide gas thru the soil. The simple method of using this indicator is described in this bulletin.

9. Insofar as the experiments with this indicator have gone, it has been found that when the penetration of the gas is indicated by the chemical, there is immediate killing of the perennial weeds treated.

10. For eradication of perennial weeds, carbon disulfide has proved to be more quickly effective and more dependable than any other method that has been tried. It is the cheapest commercially made powerful plant poison that cannot injure the soil.

11. Because of the present cost of the material and the expense of injection into the soil, carbon disulfide should be used to kill perennial weeds **on small areas only**, or on exceedingly valuable and productive land.

CARBON DISULFIDE FOR THE ERADICATION OF PERENNIAL WEEDS

CHARLES F. ROGERS[1] and IRA HATFIELD[2]

The search for a quick and economical means of eradication of perennial weeds has led to the experimental and small-scale use of carbon disulfide upon limited infestations for the protection of large areas of weed-free land. The experimental work is by no means completed, but results have been so promising that they are being made available to the people of Colorado in this progress report.

Serious Nature of Perennial Weeds in Colorado

Perennial weeds are among the most serious and destructive pests on cultivated land in Colorado. Their general distribution, their capacity to grow and spread, and their persistence make control and eradication a most difficult problem for every farmer who has infested land. Perennial weeds are always spreading by their own root systems and fragments are often dragged to new locations where infestations quickly establish themselves. The menace is increased by the dissemination of seeds, for seeds of perennial weeds can travel faster in wind, in water, or on implements than do the roots by their natural spread or by being dragged. The damage caused by perennial weeds appears as a decrease of crop yield on infested land, lowered value of and increased expense in managing the land, and decreased market value of the crops.

The noxious perennial weeds in Colorado make a formidable list. Several wild morning-glories (*Convolvulus* spp.), also known as bindweeds, are without doubt the worst weed pests of Colorado because of their general abundance and destructive nature. The poverty weeds (*Franseria tomentosa*) and (*Iva axillaris*), are native to Colorado and are nearly as widely spread over the state as the bindweeds. In Northern Colorado they are more abundant especially in the dry-land farming regions. Perennial peppergrass (*Lepidium draba*) is known in every agricultural region of the state and is, as yet, the most serious weed in cultivated and untilled fields in some parts of Colorado, but unless Russian knapweed is held in check it will soon supersede the peppergrass in importance.

Russian knapweed (*Centaurea picris* Pallas) has probably been in Colorado as long as imported Turkestan alfalfa seed has been used, but it has been known as a weed pest to farmers for only a few years.

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It has become well established and will probably invade all parts of Colorado. The knapweed is extremely pernicious because of its hardiness and its vigorous, dense growth. Canada thistle (*Cirsium arvense*) has made steady but generally unnoticed advances thruout Colorado, and is only now coming to the attention of many farmers. Perennial sow thistle (*Sonchus arvensis*) has entered the state recently from the north and northeast and is not widespread, but can quickly become so unless every precaution is taken against it. On some range and agricultural land, milkweeds (*Asclepias* spp.) are abundant. They are troublesome in the same way as other weed pests. The whorled milkweed (*Asclepias verticillata*), which persists wherever it gets started, is highly poisonous to livestock as well as being so fast and vigorous a grower that it can crowd out desirable crop and forage plants.

ECONOMIC LOSSES FROM PERENNIAL WEEDS

The losses from perennial weeds in Colorado are enormous when they are counted in money values alone. In 1917, H. R. Cates, a United States Department of Agriculture weed expert, estimated that one-sixth of the market value of a cultivated crop is expended on cultivation. He says that at least half of cultivation is made necessary by the presence of weeds. According to the 1927 Colorado Yearbook the market value for the 1926 crop of corn, potatoes, beans and sugar beets was $47,984,000. If one-twelfth of the market value is accepted as the amount expended upon these four crops in 1926 for weed control, then $4,000,000 is the estimated toll of weeds upon these four crops in one year. On the whole, perennial weeds are more destructive in uncultivated than in the cultivated crops mentioned above, but one-fourth of the loss on these crops due to perennial weeds is not too much to allow for increased expense in the production of corn, potatoes, beans and beets. A yearly loss of $1,000,000 on four crops is too much to take without any effort to stop the leak.

The question is raised as to whether or not the cost of killing the weeds to stop this loss is not greater than the return. On the basis of the returns from a single year's crop it probably is, but when the expense is taken into account for the same number of years that returns are increased, the cost of eradicating perennial weeds is not so great. Expensive measures against weeds are not justified upon large areas because the larger the area the lower the cost per unit area if mechanical means of eradication are employed. When, however, it is desirable or necessary to remove from a large area a menace in the form of a relatively small patch or patches of a perennial weed, more expensive means of eradication are permissable. The

cost should be assessed against the whole area to be protected. It should also be assessed against the time during which a successful treatment or treatments will protect the land when normal precautions are taken against reinfestations and the reestablishment of noxious weeds on weed-free land.

VALUE OF A SINGLE-TREATMENT METHOD FOR PERENNIAL WEED ERADICATION

The ever increasing menace of perennial weeds to crops and agricultural lands has created a demand for effective measures of eradication, single-treatment methods being preferred. The advantage of eradication of a perennial weed by a single treatment is that no more attention is likely to be required after the killing agent is applied. It is also possible that the agent may be used upon the pest at a time when no crop will be lost, and there will be no interference with the regular rotation of the crops. The killing agent whether put upon the tops only, or used on the roots by injection into the soil, should act in a relatively short time, and leave the soil in as productive condition as when it was applied. Whatever such a material would be, and however it is used, the roots of perennial weeds must be killed before any satisfactory and permanent control or eradication is accomplished.

IMPORTANCE OF ROOT SYSTEMS IN THE LIFE OF PERENNIAL WEEDS

Annual and perennial herbaceous weeds behave alike above ground, and cannot be distinguished by their general habits of growth. There are both annual and perennial weeds which behave as do the morning-glories or bindweeds, and many annual or biennial plants are mistaken for perennials. The way to determine the perennial nature of a weed is by its root system, or by its behavior from year to year.

Roots of perennial weeds send up from their horizontal parts vigorous stems that grow faster than seedlings in early spring and when they are unmolested, usually mature their fruit in the summer. Life resides for an indefinite period in the roots of most perennial weeds. The roots serve as storehouses of energy for the plant, and perform the ordinary function of conducting the necessary water and mineral nutrients from the absorptive region of the roots to the food-manufacturing parts above the ground. The tops of these plants may be killed repeatedly, but buds are formed upon the roots and shoots quickly develop to replace stems and leaves that have been

destroyed. The replacement of shoots draws upon the reserve in the roots.

As soon as the leaves open to the sunlight they begin to manufacture food to replace that supplied by the perennial roots. All plants depend upon their roots for the absorption of water and minerals from the soil. Perennial weeds depend upon the lower parts of their roots for their supply of water and the tops die when they are cut off from the vertical portion of the roots, even if they are left attached to the horizontal roots. Whatever the material or method used in the attempted control or eradication of perennial weeds, the effects of the treatment or treatments upon the root system are of primary importance.

THE USE OF SPRAYS

The most common method of attacking perennial weeds has been by cultivation of the soil to a depth sufficient to destroy the shoots but not to drag the horizontal roots about. If this is repeated often and long enough the roots will eventually be starved out. Use of poisonous sprays involves less labor for each treatment than cultivation or the killing of roots by injecting poison into the soil, but sprays which require many applications result in increasing damage to the soil, and the destruction of all top growth whether of weeds or crop plants.

It is possible and even probable that in the future spray poisons will be developed which can kill the roots of perennial weeds far below the surface of the ground every time one of them is applied to the leaves and stems. At the present time, spraying is easy, quick and convenient, but as it is generally practiced upon weeds the results are extremely variable. The effects of sprays cannot as yet be controlled, much less predicted under Colorado conditions. Fortunately when they are used it is not generally expected that they effect eradication of perennial weeds in a single treatment.

Highly favorable conditions are necessary for the maximum effectiveness of sprays. There must be sufficient moisture in the air to keep the sprays from evaporating quickly. This is one of the least common conditions in Colorado. The air is usually dry and has a high evaporating power which quickly reduces a liquid spray upon the leaves to a dry film. Penetration will usually be sufficient to kill the leaves and stems, but does not continue to the roots where life remains. Only under exceptional conditions do most sprays prove to be efficacious in Colorado. Sprays must be applied to weeds when their tops are fully developed, and in such quantities as will destroy

all growth above the surface, which results in loss of some crops in one of two ways. Either no crop is raised upon the infested land where the pest is developing to the stage necessary for application of the spray, or if one is planted, it is lost at the time of spraying.

A new spray, sodium chlorate, is being advertised which it is claimed will kill perennial weeds after early crops are removed and before a late crop is put in the next season. Only under such conditions can a spray be used without loss of a crop. At the time of writing of this bulletin, however, the superior value of this spray over others already tried in Colorado has not been conclusively proved.

When poisons are applied to the upper parts of plants, some of it always falls upon the ground. Almost all spray poisons that are used in quantities sufficient to eradicate perennial weeds have a residual more or less permanent effect upon the soil. The results even after an eradication with sprays is decreased productivity of the soil for several years.

USE OF POISONS INJECTED INTO THE SOIL

Contrasted with the relative impotence of most sprays as now applied for the eradication of perennial weeds in a single-to few-treatment procedure, the injection of poisonous materials into the soil when conditions are right has been found to result in the rapid and usually complete death of the plant.

CARBON DISULFIDE.—Of the poisons used in the soil, carbon disulfide has been found to be the most economical to buy and the simplest and safest to use. Its killing effects have generally become evident in from 4 to 10 days after application, but in some soils, due perhaps to the slow penetration of the poison or to the persistent nature of the plant, death of the tops was postponed for some time in a few instances, even until the following spring.

There are a number of cases on record in Colorado where there was no apparent killing of common wild morning-glory during the summer or fall of 1927, but death was almost complete by the spring of 1928. The pests either failed to appear at all or came up so weakly that a few injections of carbon disulfide near the straggling plants finished the job with no loss of crop and with relatively little repetition of work.

Furthermore, the root system is always in the ground, and can be treated at any convenient time when the conditions are right for penetration of the poison thru the soil.

BENEFITS OF CARBON DISULFIDE TO THE SOIL.—Roots of perennial weeds have been killed by carbon disulfide applied in the spring, summer, late fall and winter. Other plants grew normally upon the soil that had been treated with carbon disulfide, a short time after its injection either in the spring or summer. No difference in productivity could be noted between treated and untreated areas several weeks or months after the use of carbon disulfide, unless it was the more vigorous and rank growth of annual plants upon the carbon disulfide plots. Far from doing harm to the soil there is evidence from these plots and from much experimental work with carbon disulfide in other states that in a short time after injection there is a definitely beneficial effect upon life of all kinds in the soil. (See Figure 1.)

RESULTS OF THE USE OF CARBON DISULFIDE IN COLORADO

Altho carbon disulfide has been used in many places in Colorado to learn its powers of eradication of perennial weeds, most of the tests upon which this bulletin is based have been set up in the San Luis Valley, and in Sedgwick, Washington, Weld and Larimer counties. The test plots of carbon disulfide in the San Luis Valley were put in during June, 1927; those in Sedgwick and Washington counties the first part of July, 1927, and those in Larimer and Weld counties in May, July, September and November of 1927, and June and July of 1928. Heavy and sandy, as well as moist and dry soils were treated. Most of the tests in the San Luis Valley were in moist soil. Altho some of the plots were in open, light soil, many of them were put upon heavy clay or wet sand which gave little promise of satisfactory results. The soil in northern Alamosa county was dryer and more open, making injection easier, giving promise of better penetration and better killing effects.

In almost all of these cases the immediate killing was nearly perfect, but one treatment in southern Alamosa county was not so effective as most of the others. Inspection in 1928 of this and the other tests in the San Luis Valley revealed that in all but this one case there was a high percentage of killing. The effectiveness on the small area, however, may have been more than was apparent. When carbon disulfide was applied to this patch in June, 1927, four noxious perennial weeds, Russian knapweed, poverty weed (*Iva axillaris*), common wild morning-glory and perennial peppergrass were growing together. After practically 14 months without disturbance, and with every chance for recovery there was an apparent killing of 75 percent of the growth on this area.

Two test plots were established in Weld county, on May 13 and

16. One was on the Colorado Potato Experiment Station 4 miles northeast and the other on a farm three-fourths mile east of Greeley. The plot on the Potato Experiment Station was a rather damp, but hard and compact, gravelly loam. Penetration of the carbon disulfide gas thru the soil gave effects so quickly that the plants poisoned in the morning showed signs of wilting before the work was stopped in the evening. The other patch treated with carbon disulfide gave few signs of any damage during the summer and fall of 1927, but in the spring of 1928 the morning-glories failed to reappear excepting for a few struggling plants over the treated area.

The plots in Sedgwick county were for the most part in wet soil altho two were on rather dry soil. None of the plots where the moisture content was extremely high gave immediate evidence of any great effect of the poison, but inspection in August, 1928, revealed that two of them were almost completely killed; whereas in the third plot a wet heavy soil gave indication after a year of only a 75 percent killing. The driest soil treated in Sedgwick county was along a road northwest of Sedgwick. Here the killing was perfect, with no return growth of the common wild morning-glory during 13 months.

Figure 1.—Abundant, vigorous growth of vegetation upon ground treated with carbon disulfide the year before, showing that this chemical does not injure the soil.

The photograph of the area in Figure 1 shows that no damage was done to the soil. A rank growth of sweet clover may be seen in the background and in the foreground pigweeds are coming up thru a vigorous stand of sweet clover which had been cut once when the picture was taken.

Four plots were established in Akron, Colorado. Two were on the Experiment Station east of Akron, and two were on an intersection in town. The hard, dry, compact soil of the parking at the intersection made the work of injection somewhat tedious but the results were quick and permanent. The plots were completely bounded by morning-glory-infested land. To show the results more clearly, the photograph in Figure 2 was taken in August, 1928. It shows the weed extending across the foreground, and into the street from the edge of the parking. There is a matted mass of vines in the background next to the walk, but the area of parking adjacent to the walk and to the street where the common wild morning-glory is growing, is conspicuously free from this perennial weed, altho other plants have made rapid, vigorous and normal growth. They had, however, been cut down before the picture was taken.

Figure 2.—The effect of carbon disulfide on morning-glories or bindweeds one year after treatment. Note the absence of bindweeds in the treated area A, and the abundance of vines in the untreated area B.

A plot of similar size, but on the south side of this intersection was infested with the common wild morning-glory or bindweed, and a few plants of poverty weed (*Franseria tomentosa*). The bindweed was treated in the same way as the other plot, by making the holes 18 inches deep. The result was a perfect killing of the morning-glories without injuring the much shallower-rooted poverty weed, which by August, 1928, had taken complete possession of the soil previously held by its competitor, the common wild morning-glory.

This indicates that the depth of holes has a bearing on the kind of roots killed. Two plots on the Experiment Station east of Akron resulted in imperfect kills on both morning-glory and poverty weed. The morning-glories were on loose soil along a railroad grade, where the liquid carbon disulfide could go down for some distance instead of spreading out horizontally. The poverty weed was growing in a roadway upon the farm where the soil was compact. Holes 12 inches deep were made in the roadway. The first effects were hopeful, but in August, 1928, there had been some recovery.

In September, 1927, the central parts of several patches of common wild morning-glory or bindweed were treated with carbon disulfide. The ground was exceedingly dry and hard, even to the bottom of the holes made for the injection of the liquid poison. There

Figure 3.—Appearance of cultivated plot 10 months after treatment with carbon disulfide. Before treatment with this chemical, the weed-free area was infested with morning-glories similar to the area shown in the foreground.

was an abundance of flowers, and healthy growth, much like that shown in the foreground of Figure 3. Several days after injection, the plants close to the holes withered and died. On the whole, even until frost, it appeared that no great harm had been done to these perennial weeds. The ground was plowed early in the spring, so that no observation was possible at the first of the growing season. The soil was not disturbed again, and as the plants appeared, it quickly became evident that there was no return growth of the bindweed in these plots where the carbon disulfide had been injected. The photograph in Figure 3 shows mature plants on both sides of a bindweed-free area, the result of the treatment in September, 1927. All the plots treated in September behaved in the same way.

Results from another trial under different conditions make the use of this material for the eradication of perennial weeds more promising. On November 11, 1927, an area of Russian knapweed was treated with carbon disulfide. The infestation was on low ground southeast of Grover, Colorado, where the water table was only 4 or 5 feet down and the heavy clay soil was exceedingly moist at 5 or 6 inches below the surface. When this plot was inspected on June 5, 1928, the ground was almost bare of all growth, and only one Russian knapweed sprout was found upon the whole treated area. Large and healthy plants were growing thickly on all sides. Excavation for roots revealed that they were black and decomposed, and that only the woody parts of the root could be followed; the rest had disintegrated. Altho this may be an unusual case, it shows that the poison may kill under what would be ordinarily considered unfavorable conditions for penetration of the vapor.

Thirty-two of the tests on the killing power of carbon disulfide made in 1927 have been observed during the summer of 1928. Of this number, 7 were neither perfect nor high-percentage kills, altho none of them was below 60 percent effective. Approximately 80 percent of the tests gave results that may be considered satisfactory.

There must be, however, a greater dependability than this for a method as expensive as this one has proved to be, if it is to have a widespread use. Much labor is expended in treating even test plots with carbon disulfide, and a necessary partial or complete repetition of the treatment of an area of any size would make the use of carbon disulfide for the eradication of perennial weeds, impractical and uneconomical.

If the method of application could be made less laborious, or the certainty of killing be made greater, the use of a carbon disulfide for the eradication of small infestations of perennial weeds would become entirely practical. This would save much time that is now spent in prevention and control measures which are some times not as effective as the use of carbon disulfide at present.

The methods now employed are applicable only to small areas, but when the use of carbon disulfide is attended with certainty of results, mechanical means for its more rapid injection into the soil can be developed.

METHOD OF APPLICATION

Two ounces of liquid carbon disulfide are applied in holes 2 feet apart each way. The alternate rows are staggered so that the holes form triangles as shown in Figure 12. The holes may be made by driving sharpened steel stakes into the ground to the desired depth. The depth to which the stakes are driven depends upon the soil type; for heavy soils 18 inches has been found to be successful, and for light, coarse, sandy soils, 12 inches will suffice. Even tho the cost of application of the carbon disulfide can be reduced by making the holes a distance greater than 2 feet apart, the best results have been obtained in Colorado experiments where the 2-foot distance has been used.

Figure 4-a and b shows the method of applying carbon disulfide. A funnel is placed in the hole and the liquid carbon disulfide is conveyed from a bucket to the funnel by means of a dipper that holds exactly 2 ounces of the chemical. In order to prevent the carbon disulfide from evaporating thru the openings instead of diffusing thru the soil, the holes should be closed with dirt immediately after the liquid has been applied. In soft soils this may be done with the heel, but where the soil is dry and hard, it may be necessary to use a heavy hammer. If there is danger of the "caps" caving in, it is necessary to fill the holes before tamping. When a surplus of the liquid carbon disulfide remains unused in an open con-

Figure 4a

tainer, its evaporation can be stopped by covering with a shallow layer of water.

Figures 4a and 4b.—Photographs showing the method of application of carbon disulfide.

LIMITATIONS OF THE USE OF CARBON DISULFIDE

THE COST

Altho carbon disulfide has proved to be effective in Colorado for the eradication of perennial weeds, it has some disadvantages. Any method of underground application of a poison requires considerably more labor than does a single treatment with a spray or dust, and the work of injection will therefore be more expensive. When the price of carbon disulfide in large quantities is $5.50 per 100 lbs., the freight not more than $2.00 per 100 lbs., and the cost of injection $1.50 to $1.75 per square rod, the range of cost per acre of perennial weeds destroyed will have a maximum of from $260 to $400.

It must be remembered however, that infestations of an acre in extent can be more economically destroyed in other ways. If the area covers 10 square rods, the cost would be from $22.50 to $25.00 for the infestation, and if 20 acres were protected from and freed of perennial weeds, the cost per acre would be from $1.125 to $1.25, which should be charged over as many years as the land remains free from weeds of the kind killed. The increase in crop yield and in land value will more than repay the costs.

Carbon disulfide is much cheaper when purchased in large quantities, than when it is bought by individuals from retailers. When a number of farmers need a large quantity, they should pool their order with the county agent who can procure it from the manufacturers

at the wholesale prices quoted above.

UNCERTAINTY OF RESULTS WITHOUT AN INDICATOR TEST

As the work of 1927 has shown, not every application of the chemical has given a perfect kill. Little is known as to the exact soil conditions necessary for obtaining maximum results. The recommendations from California are that the liquid be applied while the soil is "quite dry," but under different soil conditions which prevail in Idaho, "quite moist" soil is necessary for favorable results. Good and unsuccessful results have been obtained in Colorado in both dry and moist soils. Because of the need for a better knowledge of the proper time to apply carbon disulfide, a chemical test was developed that would indicate the penetration of carbon disulfide vapor thru the soil and correlate well with the killing.

AN INDICATOR FOR CARBON DISULFIDE

During the early part of 1928 a number of chemical indicators were tried out. The chemical finally adopted as an indicator depends upon the formation of a deep yellow color when sodium alcoholate has been exposed to the vapor of carbon disulfide and treated with a solution of cupric sulphate slightly acidified with acetic acid.

Figure 5.—Vial and cord for holding the liquid alcoholate used in making the test for carbon disulfide gas diffusion.

Sodium alcoholate is prepared by allowing metallic sodium to react with absolute alcohol, and for test purposes the alcoholate is used in the following way. Small glass vials are filled with the alcoholate, and a loosely wound cotton cord is partially inserted into the open end of the vial as shown in Figure 5. Soft cord proves more satisfactory than gauze, paper, or cotton wool and affords a medium upon which to make the test. As the cord wick is never pushed to the bottom of the vial, there remains a small quantity of the liquid alcoholate which assures a check test if the reaction on the wick is not conclusive. The vials that have been used are 3 inches in length and ⅜ of an inch in diameter. They are placed in wire cages as shown in Figure 6. The cages are made from hardware cloth which is rolled into a cylinder. These cages afford support and protection for the vials, and furnish an easy method for injecting them into the soil. The wire A is used for inserting the cage into the soil and for removing it at the time the test for the formation of the yellow color is to be made.

In order to test the distance of diffusion of carbon disulfide gas thru the soil, the cages are

placed in holes arranged as diagrammed in Figure 7. The center hole, marked O indicates the dosage hole,, the point of application of liquid carbon disulfide. Three spiral lines of holes are used, for it is advantageous to disturb the soil as little as possible. The dots on the curves marked 1, 2 and 3 indicate the points where the test cages are placed. In each of the 3 rows of test holes, the first is 4 inches from the center, the second is 8 inches, the third 12 inches, and the fourth 16 inches.

The length of time intervening between the application of the carbon disulfide and the time of testing for the yellow color depends upon the distance of the indicator from the dosage hole. It is convenient, however, to apply the carbon disulfide one day and to leave the test vials in the ground until the following day before making the tests. This usually allows ample time for the carbon disulfide gas to reach approximately its maximum distance of diffusion.

Figure 6.—Diagram of wire cage used in inserting the indicator tests into the soil.

The cages are pulled up, the vials removed from them, and with a small quantity of the acidified cupric sulphate, tests are made separately upon the wick and the liquid sodium alcoholate in the bottom of the vial. The change of the wicks or alcoholate to a deep yellow color, shows that the carbon disulfide vapor has penetrated the soil from the dosage hole to the indicator. If the string or liquid alcoholate takes on a blue-green tint instead of the deep yellow, it is not likely that carbon disulfide has penetrated the soil in quantities sufficient to kill roots of perennial weeds.

Figure 7.—Arrangement of test holes for determining the diffusion of carbon disulfide gas thru the soil from "O", the point of application.

Experimental data show that the use of this indicator method is advantageous, for in the test plots of 1928 there is high correlation between indication by the alcoholate and the killing of the weeds treated with carbon disulfide. In the test plots where the indicator failed to register penetration, apparently the weeds were not killed, but whenever a bright color change was obtained, a good kill followed.

Figure 8 shows a profuse growth of common wild morning-glory or bindweed along the curbing on Mathews street in Fort Collins. A portion of this plot was treated with carbon disulfide and indicator tests were made. The indicator recorded a high percentage of penetration which would suggest that a good kill would follow. Figure 9 shows the kill obtained.

Figure 8.—Photograph of a profuse growth of common wild morning-glory along street curbing.

Figure 9.—Photograph of morning-glory plot adjoining that of Figure 8, after treatment with carbon disulfide.

Figure 10.—Photograph of morning-glory plot 20 days after application of carbon disulfide.

Another plot was staked out on a piece of plowed ground and the carbon disulfide injected. Carbon disulfide penetration was indicated in every test hole. Figure 10 is a photograph of the plot 8 days after application of the chemical. On each side of the plot may be seen the dense growth of the wild morning-glories, whereas in the treated portion there is already a striking reduction in the number of plants.

A further example of the correlation of indication with killing is shown in Figures 11 and 12. Figure 11 is a photograph of a plot of poverty weeds (*Franseria tomentosa*) on irrigated land. A good indication and satisfactory results were obtained around the edges of the plot, but in the central portion there was no indication and little or no kill. Figure 12 is a diagram of this same plot. The circles mark the points of application of the carbon disulfide and the dots designate where the indicator tests were made. "T" is placed beside the dots where penetration was indicated, but a failure to get a test is marked "NT." Irrigation water had recently stood upon the area indicated by the shading in Figure 12, whereas the remainder of the plot was "quite dry." The tests showed that there was no penetration in the moist area, and from Figure 11 it may be seen that practically none of the plants in this area was killed.

Figure 11.—Photograph showing a poverty-weed plot after treatment with carbon disulfide. The growth shown in the middle of the plot was the point where there was no indication and no killing.

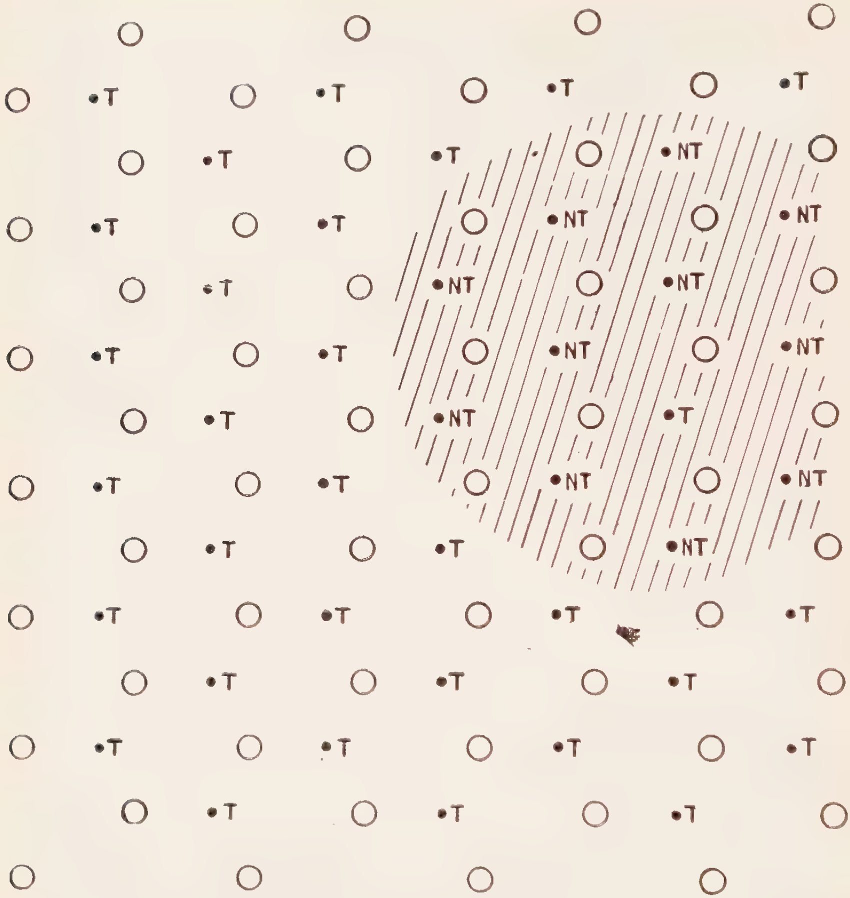

Figure 12.—Diagram of the plot photographed in Figure 11, showing the correlation of indication and killing.

From the experimental data collected from a number of such plots, a good killing always followed a good color indication, and when there was no indication of the penetration of carbon disulfide, the plants survived the treatment.

RECOMMENDATIONS

Carbon disulfide can be recommended as an effective and economical means of eradication of small patches of perennial weeds when large areas of weed-free land are to be protected from invasion.

Treatment with carbon disulfide can be made at times when farm work is slack, provided that the soil is in proper condition for penetration of the poison.

The chemical indicator discussed in this bulletin may be used for determining the penetration of carbon disulfide gas thru the soil and the probable effectiveness of this material for the eradication of perennial weeds under existing conditions. It should be put in representative places in each plot to be treated. Only when it shows penetration of carbon disulfide gas should the poison be used upon the whole area. It is well to treat the plot immediately after a satisfactory test, because soil conditions may change and modify the rate of penetration and the killing power of the poison.

Some of the material for this test is not readily available. It is therefore well to have the county agent or one who is familiar with the handling of chemicals make these tests. Indicator solutions ready for use, are available at the college for county agents. They may be had upon application by the county agents to the Botany department.

Two ounces of liquid carbon disulfide should be applied in holes 2 feet apart in the manner suggested in this bulletin. These application holes should be 18 inches deep for heavy soils, and 12 inches deep for light, coarse, sandy soils.

When carbon disulfide is purchased in quantities of more than 1000 pounds there is a material saving over the price paid for small lots. Farmers should unite their orders into a single large purchase.

When a number of farmers desire to purchase carbon disulfide, their county agent can obtain it at wholesale price direct from the manufacturer and at a material saving for them.

WARNING

Carbon Disulfide is Highly Inflammable and Explosive, Hence Extreme Care Should Be Used to Keep It Away From All Free Flames.

Its vapor has an injurious effect upon the human system. Large quantities of the fumes should not be inhaled and care should be taken to avoid getting the liquid into the eyes or mouth. It does not damage clothing or shoes.

In order to prevent loss by evaporation, the carbon disulfide should be kept in a tightly closed container.

Bulletin 348 October, 1928

CANADA THISTLE AND RUSSIAN KNAPWEED AND THEIR CONTROL

By Charles F. Rogers

Colorado Agricultural College
Colorado Experiment Station
Fort Collins

The Colorado Agricultural College

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*On leave, 1928-29.

CANADA THISTLE AND RUSSIAN KNAPWEED

SUMMARY

Canada thistle and Russian knapweed, two of the worst weeds known to agriculture, are found associated with all crops and almost every kind of soil, and in every agricultural region of Colorado. Their distributions in Colorado are shown in Figures 2 and 11.

Canada thistle has characteristic stems and leaves which together with its extensive perennial root system make identification easy. Its leaves, stem, flowers and fruit are shown in Figure 1.

The Canada thistle has large horizontal roots where food is stored for use in the replacement of the above-ground parts of the plant and for the extension of the root system. Shoots are sent up from buds on the roots as often as the tops are killed.

The shoots that come up in the spring are formed early in the winter, and grow during the time the ground is frozen.

Roots of Canada thistle can grow horizontally thru ordinary soils as far as 20 feet in one season. A single horizontal root grows in a given direction for 2 to 4 feet and bends down as shown in Figure 3. Another root arises at the bend, and continues the course of the mother root.

Under normal conditions roots of the Canada thistle live in the soil for two seasons. When the tops are destroyed by cultivation or other treatments, this time may be shortened or extended.

Vertical roots of the Canada thistle have been found 22½ feet below the surface of the ground. They absorb most of the water and mineral nutrients for the leaves and stems. The kind of soil in which the Canada thistle is growing has much influence upon its development. Sandy and hard-pan soils are least favorable, and moist clay is most suitable to the growth of roots and tops of the Canada thistle.

Russian knapweed described in this bulletin, has shown no definite association with soil types in Colorado. It is usually found upon land once planted with imported Turkestan alfalfa seed.

The presence of the seed of this weed in alfalfa seed imported from Russian Turkestan has given the knapweed its name and made probable its establishment in every place where Turkestan alfalfa seed has been planted.

The horizontal roots of Russian knapweed are similar to those of Canada thistle, but they are shallower, more fibrous, have less

storage region in each root, and have more roots near the surface of the soil. The vertical roots penetrate deeply into the soil, in some instances to the water table. The length of life of the roots of Russian knapweed is probably the same as that of the Canada thistle.

Excepting for a number of minor differences the noxious characteristics of the Canada thistle and Russian knapweed are the same. Both plants are among the most persistent of the perennial weeds of Colorado.

When these pests are allowed to grow unmolested, they make so dense a stand that almost no plants can compete with them.

Both the knapweed and the thistle damage hay by making the hay difficult to eat, or unedible. They damage pasture by invading the sod and crowding out good forage.

Viable seeds of the Canada thistle are produced wherever the staminate and pistillate plants are growing near each other. Seeds with high percentage of germination have been collected from several places in northern Colorado.

The seeds of Canada thistle and Russian knapweed can travel great distances. Those of Canada thistle are often carried by a strong wind to places far removed from the old plants. If seeds of either Russian knapweed or Canada thistle fall into flowing water they endanger the land below them.

These two pests travel in impure seed, for Canada thistle is a common impurity of commercial seeds of many kinds. The most abundant, important and dangerous impurity in the Turkestan alfalfa seed released from the Denver Customhouse in March, 1928, is Russian knapweed seed. None of this alfalfa seed should be planted before a purity test has been made by the Colorado State Seed Laboratory.

The best way to keep any perennial weed out of a locality is to use *clean seed*, to clean all farm machinery before it leaves the place where it has been used, and to prevent flowering and seed production of all infestation.

Fresh manure is a common source of weed infestation because seeds of many weeds are not killed by passage thru an animal. Manure should be allowed to decompose before it is spread upon the land.

Prevention of weed infestations by the use of clean seed, clean hay and well-rotted manure, together with the elimination of seed formation, is the cheapest way to keep free from weeds of any kind.

The natural increase in the size of an infestation due to the yearly extension of roots is from 6 to 20 feet a year.

The surest means of protection from an existing infestation is eradication, but if this is not possible, the patch should at least be treated separately. No roots should be dragged to other parts of the field or farm. Complete isolation of the infestation is the first step toward its elimination when conditions for eradication are suitable.

Proper control measures for perennial weeds assist in ultimate extermination. They should consist of the prevention of seed formation by mowing and spraying, the burning of mowed weeds, separate, clean cultivation of infestations, clean fallow at intervals, crop rotation, and smother crops.

The general principles upon which eradication measures are based are starvation of the roots or the direct killing of the roots.

The roots of perennial weeds can be starved when such practices as clean cultivation or fallow, spraying and smothering are properly and consistently carried out.

There are numerous commercial sprays with varying value sold in Colorado. Perennial weeds can be smothered by using either crops or dried material. Smother crops should be quick, vigorous, consistent growers, and should be able to hold the weed in check at all times.

Straw, manure and stack bottoms can be used on small patches. Any one of these smothering materials must be kept moist so that decomposition will be active, and it must be kept deep enough to prevent stems from penetrating thru to sunlight.

Sheet metal and paper have been used successfully on very small patches of perennial weeds. Cost of material makes this method prohibitive for large areas.

Direct killing is a way of eradication of perennial weeds which depends upon a sudden death of the roots and tops of the plant.

Some sprays are claimed to be powerful enough to almost entirely eradicate a plant in a single treatment. This has not been found to be the case with any of those tried out at the Colorado Experiment Station. Sodium chlorate has, however, given more promise than any of the others.

Digging out of very small patches or of seedlings proves a sure way to eradicate perennial weeds.

Killing the roots underground avoids the danger of spreading the roots about by dragging, and is further advantageous in that a single treatment often suffices.

Carbon disulfide has been found to be a useful and reasonably certain method for eradication of small infestations in a short time. It is not practicable for large areas, but is recommended where it

is desired to *protect* large areas of weed-free land. Carbon disulfide cannot damage the soil and its poisonous effects are temporary.

Salt is expensive to purchase, and hard on the soil. It will kill out any vegetable life when it is applied at the rate of 2 pounds to the square foot. When it cannot be washed out by flooding, it permanently injures the soil. It is particularly valuable in keeping weeds out of feedlots and other untillable land.

CANADA THISTLE AND RUSSIAN KNAPWEED

By Charles F. Rogers*

The "Canada thistle," one of the worst weeds known to agriculture the world over, has for some time been a resident of every agricultural region of Colorado, but it has not been given the attention its abundance in the state merits. A more recent immigrant to the Rocky Mountain States is the Russian knapweed, which at present infests chiefly alfalfa fields or areas once planted to alfalfa, for it has been introduced in imported Turkestan alfalfa seed. It too has been found in every important agricultural region of Colorado, but it is not well known because of its close association with alfalfa and its relatively recent discovery in the state.

Because of the numerous inquiries for information on these two weeds, and the samples sent in to the College and Experiment Station for identification, this bulletin has been prepared to acquaint the people of Colorado with the Canada thistle and the Russian knapweed. The plants are described and illustrated to show their distinguishing characteristics so that those who are not familiar with this thistle and knapweed can recognize them. The principles and methods of prevention, control and eradication given in this bulletin are based upon experience with the Canada thistle and other perennial weeds during the last 200 years in Europe and America. Altho experiments upon the control and eradication of the Russian knapweed as yet have not been conducted extensively in this country and none have been completed in Colorado, the habits of this new pest are so similar to those of the Canada thistle that the methods which are effective for the prevention, control or eradication of the thistle are almost certain to be effective upon the Russian knapweed as well.

THE CANADA THISTLE

The Canada thistle (*Cirsium arvense*, (L.) Scop.) also known as creeping thistle, field thistle, cursed thistle, and by many other local names thruout the world, is an introduced perennial that propagates itself by both seed and perennial roots.

Detmers† in Ohio says that "The Canada thistle is readily

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*Assistant Botanist and Deputy State Entomologist, in charge of weed control, 1925 to 1928.

The writer wishes to thank Dr. L. W. Durrell for assisting with the manuscript, the preparation from original material of Figures 1, 4, 9 and 10, and for copying from Lund and Rostrup (loc. cit.) Figures 3, 5, 6, 7 and 8. Much credit is also due Ira Hatfield and Miss Anna M. Lute for generous assistance with the manuscript.

†Detmers, Freda: Canada Thistle, *Cirsium arvense* Tourn. Field Thistle, Creeping Thistle. Ohio Agric. Exp. Sta. Bul. 414:1-45. Nov., 1927.

distinguished from all other thistles by its deep green, intensely spiny leaves, small heads of flowers bourne in clusters, by growing in patches and by its horizontal branching root."

DESCRIPTION

LEAVES AND STEM.—The leaves and stem of this thistle are distinguishing characteristics. The erect, ribbed, spiny stems arise from the numerous buds and knobs of the horizontal roots. They are usually green, but in places where exposure to light is great, they are often brown or purple near the base. The leaves are normally dark green and shiny on the upper surface, with a white hairiness on the under surface, especially if the leaves are young and vigorous. The blade of the leaf is long and narrow, and the lobes are terminated with spines as shown in Figure 1-A. The edge of the leaf has several orders of lobes, and is sometimes so "ruffled" that it appears almost ragged. The leaves are sessile, that is they have no "stem." Sometimes the base of the blade clasps around the stem, giving it the appearance of being more spiny than it really is. The stem is often much branched, with the higher branches more vigorous. These in turn are branched several times, and bear flower heads at their tops. (Fig. 1-B.)

Shoots sent up from the roots in the late summer or fall, seldom develop stems above the ground, but remain as flat rosettes of leaves (Fig. 3). Here they are protected from the early frosts and often keep alive long after the stalks have been frozen. All shoots, including the flowering stalks, first appear in the rosette stage.

FLOWERS AND FRUIT.—The numerous purple heads are much alike on all the plants of the Canada thistle. They are 2/5 to 3/5 of an inch in diameter, and 1/2 to 3 5 inch long. The pollen is produced by one plant and the seed-bearing parts are on another plant that has a separate root system. The staminate flowers have a sterile ovary with a poorly developed style and stigma. In the pistillate plants the stamens remain undeveloped, but the stigma matures and the ovule grows normally which means that only those plants, in which the egg develops, can mature seed. This explains the common idea in many localities that the Canada thistle produces no seed. It is entirely possible that this is true, because if only one kind of plant, either the staminate or the pistillate, is growing isolated from other Canada thistles, fertilization cannot take place. The staminate flowers can of course bear no fruit, and without the pollen from them, the pistillate plants remain unfruitful. It is known, however, that when the two plants are growing close enough together there is plenty of fruit. Viable seed was collected within 4 miles of Fort

Fig. 1.—Drawing of the details of the leaves, stems, heads and flowers of the Canada thistle.

A.—A lower leaf and a section of the stem.
B.—Top of a flowering stalk which shows arrangements of heads.
C.—Pistillate flower.
D.—Staminate flower.
E.—Seeds from the center and edge of the head.
F.—Canada thistle seed with pappus or down.

Collins late in the summer of 1927, and was shown to have a high germination test almost immediately after collection.

Lund and Rostrup* who observed this pest more than 60 years ago in Denmark, state that both the staminate and the pistillate plants produce close to 10,000 flowers on a single stalk in a season. Only a small proportion of the seed ever matures into ripe fruit, but even with this there is always an abundance of good seed, whenever the conditions are favorable.

Under normal conditions of sunlight and moisture in Colorado the flowering will start in June and continue until August. Many of the stalks will have some heads open with light brown "down" floating away on gusts of wind, while other heads are purple with fresh flowers. The two kinds of plants can be distinguished by the mature heads, or by the freshly opened flowers which are shown in Fig. 1. The petals of the pistillate flowers are shown in Figure 1-C, to be much smaller than those of the staminate flowers (Fig. 1-D). The staminate flowers have petals 1/5 to 7/25 of an inch long, whereas those of the pistillate flowers are only 3/25 to 1/5 of an inch long. When the staminate flowers open, they give off a strong perfume much like vanilla, but the pistillate heads have more the odor of the "thistle rust" which will be discussed later.

Then too, there is a difference between the mature heads. When the flowers fade, the pappus, shown close to the tube of the flowers in Fig. 1-C and D, begins to grow in the pistillate head and becomes twice its original length. The pappus in the staminate head, however, is not quite so long at first and does not grow after the flowers fade. The mature seed-bearing heads therefore look much larger and are more fluffy than the faded pollen-bearing heads. The "down" is a light-brown color in the heads which contain seeds, but it does not show plainly thru the dried petals of the staminate heads, which remain a dirty brown and never open up after the flowers have died.

Figure 1-F shows a seed attached to the pappus. The larger thread-like branches are covered with minute "hairs" which increase the carrying power of this contrivance for dissemination. When the seeds are still in the head and the "down" is moist, all the branches are drawn together with their ends pointing upward. As they dry out, the branches spread, and the finest divisions stand straight out. Several repetitions of this movement serve to pull the seed from its position and drag it out to where the wind can easily carry it away.

The seed is 1/10 to 1/8 inch long, and about 1/25 of an inch

*Lund, SamsΦe, and E. Rostrup: *Marktidselen, Cirsium arvense*. D. Kgl. Danske Vidensk. Selsk. Skr. 6, Raekke 10:148-318. 1901.

thick. Those that grow in the center of the head are straight, but they become more curved as they are found nearer the edge. (Fig. 1-E.) When ripe the seeds are tawny.

Occurrence and Habits of Growth

Association With Crops.—Crops in general do not have much effect upon the growth of the Canada thistle or upon the Russian knapweed. The Canada thistle thrives in small grains, gets along well in cultivated crops as ordinarily managed, survives almost any kind of pasturing including good sod, and can hold its own for a time in competition with smother crops. It does not spread rapidly in sod, and is seriously checked by continued trampling, but in cultivated or grain crops, unless given constant attention, it quickly gets the upper hand and spreads rapidly by horizontal roots.

Association with Soils.—To the same degree that the Canada thistle infests most crops, it may be found on all soils except peat. Brenchley* records that in 812 fields observed, this thistle was dominant 125 times, and held a higher rate of occurrence per 100 fields than any other weed. In the Central and Northern States it grows most luxuriantly on limestone soils where water is abundant. The thistle has been found in dry places in Colorado and has persisted for more than 25 years on unirrigated land in the city of Fort Collins. On extremely wet soils with a high water table, the growth is weak, and the root development is poor and shallow. This relation is discussed more fully under the root system.

Range

Distribution in Colorado.—The writer has seen the Canada thistle growing in several places about Grand Junction and Montrose and had a report of it from Del Norte, which was later verified by a specimen. The thistle has been seen growing along the railroad right-of-way in Salida, and is known from specimens to be in the upper and lower parts of the Arkansas Valley. Specimens have been sent to the College from Weld County and the pest has been located in at least four large areas close to Fort Collins. Because no survey of the state has been made to discover all the regions it infests, it is not possible to give every location, but in view of the time it has been known to be in Colorado, this thistle is certainly more widely distributed than the map in Figure 2 indicates. It has not been generally recognized by the people of Colorado as one of the worst weed menaces to their agriculture.

Distribution Over the World. Every agricultural region in

*Brenchley, Winifred E.: Weeds of Farm Land. 1920. X. plus 239 pp. illus. New York: Longmans, Green and Co.

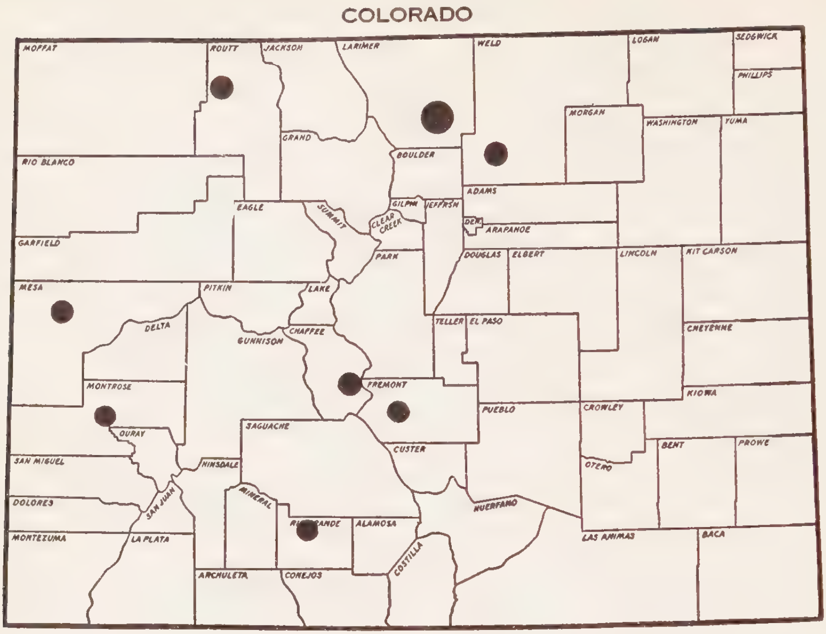


Fig. 2.—Map showing the known distribution of the Canada thistle in Colorado.

the United States, north of the line from Virginia to central California is infested to some degree with the Canada thistle. In the Dakotas and in Canada, stringent legal measures are in force which require that the plant be destroyed wherever found. In these regions seed formation is more common, general development is more vigorous, and infestations are larger and more numerous than in Colorado.

Every agricultural country that has imported seed from Europe is troubled with this most destructive weed. New Zealand and South Africa have struggled with it because the first few plants were not eradicated as soon as they got started.

Uses

Almost any plant can be used in some way, and the Canada thistle is no exception. When the shoots and roots are taken early in the spring before the leaves have pushed thru the surface of the soil they are tender and tasty, and can be used in the same ways as asparagus. Both the shoots and roots are reported to have been eaten in Russia, and by the Indians in this country. When in flower, the fragrant perfume attracts insects, and the nectar is considered in some places to make good honey.

Root System

Horizontal Roots.—The tops of the Canada thistle die down

to the ground after the first heavy freeze, but the roots remain alive during the winter. There are many horizontal roots which lie parallel to the surface of the soil at depths which depend upon the nature and the moisture content of the soil. They are most commonly found from 6 to 12 inches below the surface. Figure 3 shows the interrelation of the roots and how they bend downward after they have grown horizontally for several feet. These horizontal roots together with the vertical roots are the storehouse for the food made by the leaves during the summer, and the most important means of extension of the plant in the soil. Usually they grow horizontally for 2 to 4 feet before making the wide bend into the subsoil. Almost always a new horizontal "regenerative root" arises at the bend, and takes the same direction as the mother root. A number of feet farther on, it too will bend down. This may be repeated several times during a season, so that the spread of the Canada thistle thru the soil is rapid. It is sometimes as much as 20 feet in a season, when the growing conditions are favorable.

Certainly the horizontal roots are the most important part of the plant when control measures are to be considered. The horizontal roots are largest at the bends, and bear most of the stalks upon the sharper parts of these curves, as is shown in Figure 3. There are almost no small roots that come off from the horizontal roots, and absorption from the upper levels of the soil is largely limited to the fibrous roots that are found upon the underground portion of the stem and the very young horizontal roots. The horizontal roots, are, therefore, practically unable to live independently of the vertical roots which descend into the subsoil when they have a full load of tops to support.

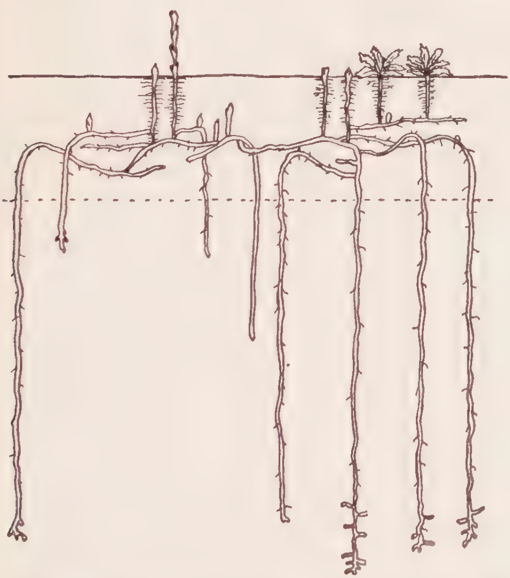


Fig. 3.—Diagrammatic sketch of root system of the Canada thistle.

Vertical Roots.— The vertical roots grow into the subsoil according to the nature of the soil and the need for water and mineral nutrients. After the roots assume the vertical position, they have an abundance of small branches for absorption. It is upon these parts of the plant that the upper roots and the aerial portions depend for their general vigor and continued extension, because this region together with its functions of absorption, is one of the chief places for storage. Figure 4-A is a cross section of a root of the Canada thistle which shows its cellular structure and the wide ring of large storage cells where the food is kept and changed into the forms in which it can be most easily used. The diagram of the thistle root in 4-B gives a simpler picture of the relative proportions of the storage region "S" to the conducting or vascular region "V."

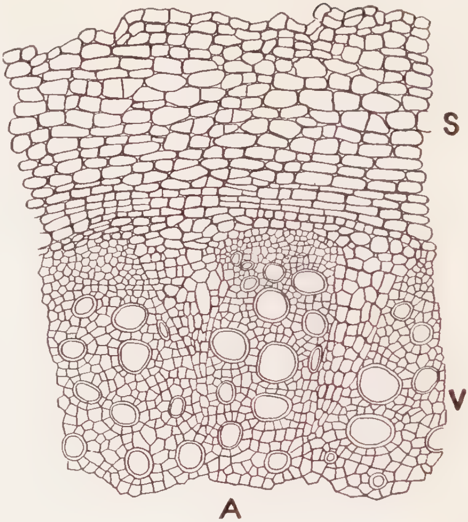
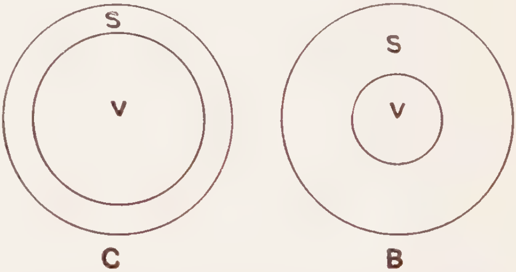


Fig. 4.—A.—Cross section of a root of the Canada thistle showing the conduction and storage regions. "S" is the storage region of the root. "V" is the vascular or conducting tissue.



B. and C.—Cross section of roots of the Canada thistle and Russian knapweed showing the relative conduction (V.) and storage (S.) regions of each.

DEPTH OF PENETRATION OF ROOTS.—Unless the water is far down the roots frequently reach the water table. A depth of more than 8 feet was reported from Denmark by Lund and Rostrup*, and excavations made by the author in Iowa and Colorado showed that depths of 7½ to 9 feet are common. One digging in the dry region of the steppes of southeastern Russia found the ends of roots of the Canada thistle at a depth of 22½ feet below the surface. The root is fairly uniform in size thruout its vertical length.

EFFECT OF SOIL UPON THE ROOTS.—The kind of soil in which the roots grow greatly modifies their development, and consequently their absorptive and storage capacity. Unfavorable conditions in the subsoil always result in a poor growth of tops and a weak root system. Hard-pan soils, gravel, sand or a high water table decrease the depth and retard the rate of penetration of the roots. If the root tip is destroyed during its growth by striking marly soil, a stone, or other obstacle, branches are usually sent out to continue the same direction of growth. Gravel or sand affects roots in much the same way as does hard-pan or marl. The effects of different soils upon root growth are shown diagrammatically in Figures 5 and 6. Moist clay always seems to furnish the best medium for development of perennial weeds. In Figure 5-A is seen a root of the Canada thistle growing in clay which is underlaid with marl. The tufted branches indicate the level of the hard-pan. Much better development is evident in Figure 5-B because the soil in this case is a soft homogeneous clay, but is underlaid at a considerable depth by marl, at which level the branches always become tufted. When gravel is covered by a thin layer of clay, the roots take the position shown in Figure 5-C. The roots form in the soft soil, but cannot penetrate the rough gravel. If the hard-pan is at the surface, the roots have many small short branches, as is shown in Figure 6-A and B, but if the layers below are soft and moist, a root will sometimes find its way into the more favorable regions and help support the plants above. Sandy soils, however, give little comfort to perennial roots

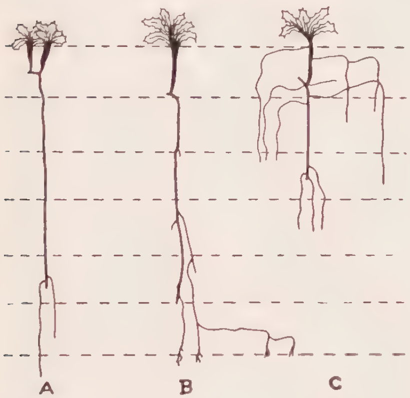


Fig. 5.—Development of the roots of the Canada thistle in clay.
A. and B.—Clay underlaid with marl.
C.—Clay underlaid with gravel.

*Loc. cit.

of this kind, for they remain shallow, short and weak (Fig. 6-C). It can be clearly seen that the kind of soil upon which the Canada thistle is growing is a large factor in the vigor and resistance of the plant to efforts at control, and has a major role in the means employed for complete extermination.

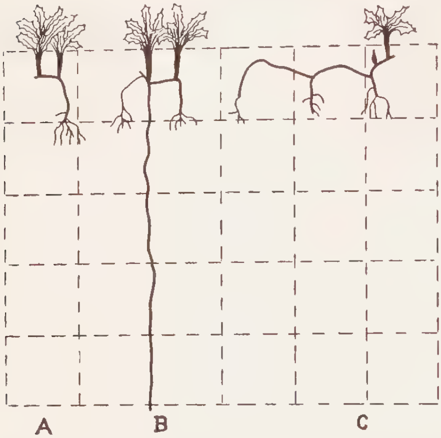


Fig. 6.—Effects of hard and sandy soils upon the development of the roots of the Canada thistle.
A. and B.—Hard-pan near the surface.
C.—Development in sand.

SIZE OF ROOTS.—The size of the roots has the same relation to different soils as does the extent of the root system. Clay furnishes the best medium for development of individual roots as it does for the whole plant. Roots 3/4 inch in diameter have been taken from moist, soft clay by the author. These diameters were found at the bends of the roots where they start into the subsoil. Below the bend the roots slowly taper downward, but they are fairly uniform in size thruout their vertical length unless they are stopped by unfavorable soil, or by a high water table. The coarser and harder the soil, the smaller the roots are likely to be. The decrease in diameter in places where there is high water table, sand or hard-pan, is partly due to starvation of the roots because of the poor top growth, and partly due to the frequent branching that occurs when the tips die and new tips are formed. Roots in sand never becomes more than 1/4 inch in diameter, and the proportion of the storage to conducting tissue is smaller than when the roots are large, and the leaves are sending down an abundance of surplus food for storage.

LENGTH OF LIFE OF ROOTS.—Altho the Canada thistle is a perennial plant, its roots, unlike many of the woody plants, do not live indefinitely, for they pass thru a definite life cycle. New roots keep taking the place of those that die, and the infestation seems to remain the same when it is really being constantly renewed.

A root which is formed early in the spring will reach its full development the same summer, but probably will not produce flowering stalks. The shoots it sends up will have many leafy stems, and will assist in the accumulation of the reserve supply of food and energy to be used the next spring. These tops die down to the root

in the winter unless they are infected with the "thistle rust," in which case the lower end of the underground part of the stem will probably live over winter, and send up sickly shoots the following spring.

During the second season for the root, it produces large flower stalks. In the meantime young roots have been growing out from the old one, and have penetrated the soil in all directions. During the summer of 1929, therefore, the greatest activity of the 1928 root is reached. It quickly falls into decay after the death of the tops and in the spring of 1930 the root will be nothing but a dead black form with a shredded string in the center, which was the conducting tissue. Roots which are hindered by smothering or by other interference, do not follow this cycle so closely, and are usually longer lived because their normal development has been interrupted.

Noxious Characteristics

Those characteristics of a plant that make them noxious are not in themselves undesirable. The very habits that make a grass form a good lawn or pasture are noxious when exhibited by the Canada thistle or the Russian knapweed. Persistence, capacity to spread, either by root or by seed and density of growth, may or may not be advantageous. In the Canada thistle and Russian knapweed they are decidedly troublesome.

Persistence.—Something of the life history of the Canada thistle has already been presented. One of its worst characteristics is its ability to retain its hold upon life, and the soil in which it is established. There is no record of an area infested with this plant ever having died out from natural causes, and the records of the successful attack upon the thistle by man are altogether too few. Many fields and even whole farms have been abandoned, because the Canada thistle had got the upper hand in the struggle. A field near Ontario, Iowa, has been infested with this thistle for 40 years, and efforts have been made to check the invasion, but it has spread steadily. This persistence is accounted for by the large amount of food stored in the roots.

Capacity to Spread.—Coupled with this persistence is a great capacity to spread. The natural increase in the size of an infestation has already been explained. This in itself is one of the worst characteristics of the Canada thistle.

When small sections of roots are broken from the main system they have phenomenal powers of regeneration. The roots of this pest have, as do many other perennial weeds, the capacity to form in a short time a whole new plant from a fragment of root that is supplied with food, and which is more than 6 weeks and less than 2

seasons old. Figure 7 shows a small section of root that was broken off and dragged in the early summer from the original infestation. During the remainder of the growing season, it sent up a stalk from near one end, and produced many horizontal roots. The infestation from this small piece is already more than 9 feet across. Instead of being unusual this is the common occurrence in fields where the areas covered by perennial weeds are plowed or cultivated at the same time as the thistle-free ground. If they are not exposed to direct sunlight, or to desiccating winds, these detached sections of roots can live for some time in a rather dry soil.

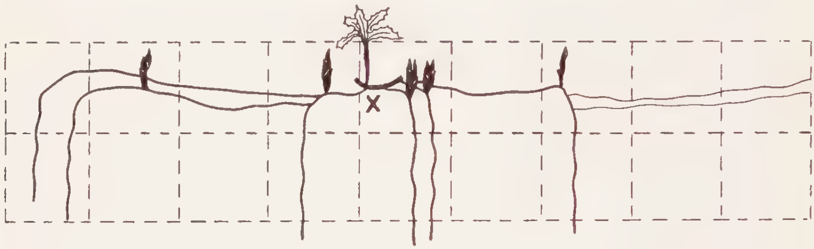


Fig. 7.—Growth during one season of a root system from a section of a root. X.—Original section of root.

When conditions become favorable for regeneration, the buds quickly develop, and grow into astonishingly large and healthy plants for the apparent amount of reserve in the fragment of root. As soon as the leaves unfold above the surface of the soil, the new system quickly becomes self-supporting. The reserve food in the old root, however, is soon used up either in the extension of the roots, or in the production of new shoots. Deep cultivation thru patches is therefore unwise because of the great danger of spreading the pest, without doing serious damage to any established plants. Natural extension of 20 to 40 feet a year under favorable conditions, gives sufficient cause for anxiety, but the vitality of the pieces of root makes it necessary to use methods that do not drag the roots over weed-free land.

Any noxious plant that spreads by wind-blown seed is likely to become a serious pest. The most rapid and widespread natural means of dissemination of the thistle is by its parachute-provided seed. This characteristic of the thistle makes it a constant menace for many miles in all directions from the place where viable seeds are produced. The seed may be shaken loose by the wind and dropped into flowing water which irrigates land many miles away. Infestation commonly caused by dissemination of seed by either wind or water, are inexcusable, for it is entirely possible to prevent seed formation by cutting the stalks when the flowers begin to open.

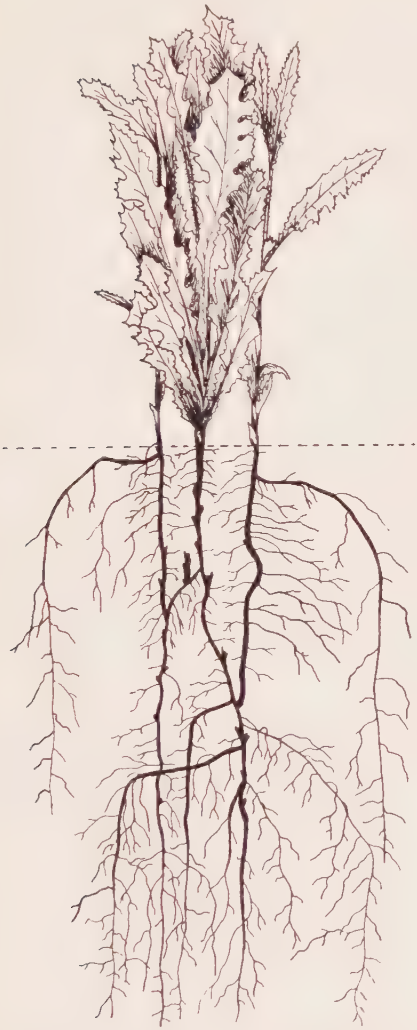


Fig. 8.—A seedling of Canada thistle grown in sand for 10 months. Note the development and formation of buds upon the bends of the roots.

Some of the seeds will germinate the same year they are matured, but most of them will not grow until the following spring. Those that do start late in the summer will become not more than 6 to 10 inches high, and some will fail to live over the winter. When the seeds germinate in the spring, however, they grow quickly into large plants with stalks 20 to 24 inches tall. Except that they are unlikely to flower the first year, they can in no way be distinguished from an old plant. Lund and Rostrup* allowed a seedling to grow in sand for 10 months. The box which held the sand was nearly 3 feet deep, practically as long and about a foot wide. They broke the box apart to expose the roots in their natural position. The development of the roots in the sand is shown in Figure 8. If development like this can take place under such unfavorable conditions, it can readily be seen what will happen in the field.

Impure seed is one of the easiest and most common means of introduction of the Canada thistle into a new region. It is found in clover seed more frequently, in Alsike clover, and in uncleaned grains from infested fields. It occurs in most kinds of seeds.

One of the easiest ways to carry the seed from place to place in a locality is on and in farm machinery. Wagons, hay racks, threshers or combines are good carriers because the seeds shatter out of the heads and collect in the cracks and on the non-moving

*Loc. cit.

parts of the machinery. They rattle out during moving, or are dumped out when the thrashers or combines are cleaned before starting a new run, instead of being left at the place where the previous job was completed. A few moments spent in the prevention of spread of weeds from one field to another will save probably years of effort on the same or on a neighboring farm which previously had been free from the pest. The spread of any weed in this way, when prevention is so easy, can find no excuse whatever.

When the seeds of Canada thistle are fed in grain most of them pass thru the animal without injury and are able to grow when they are spread upon the land in fresh or undecomposed manure. At the time the grain is thrashed many viable seeds are of course blown out with the straw from infested fields. After being used for bedding, the straw with its load of thistle seed is carried to the field again. Poor hay which contains mature thistle plants is sometimes fed to animals. Many of the mature seeds remain in the hay, and return to the field in the manure. These means of dissemination add to the noxious characteristics of the Canada thistle by increasing the ways in which it becomes dangerous.

DENSITY OF GROWTH.—When the Canada thistle has become well established, the shoots come up so thickly that the soil is completely covered. If this happens in grain fields, the young grain is choked out or seriously checked in its growth. Thistles in a pasture are usually so completely left alone by livestock that the spiny plants grow unmolested. The edible pasture plants are, therefore, crowded out and the pest more strongly entrenched than ever. Ordinary practice in the cultivation of corn holds the thistle down for a while in the spring. After the corn is laid by, the thistles can sometimes so nearly overtake the corn that it grows little after the last cultivation.

The growth of the Canada thistle is much greater in full sunlight than in full or even partial shade. Altho it never flowers when completely shaded, its capacity to compete successfully with other herbaceous plants is nearly as great in the shade as it is in well-illuminated locations.

PRESENCE IN HAY AND PASTURE.—Canada thistles which grow in hay meadows are usually kept under control and are unlikely to mature much seed. They are, however, present in the dried hay where their coarse leaves and stems would make poor forage even if they were free from spines. Hay which has many thistles in it is useless for fodder, and has little value as bedding. It is dangerous to use it as a fertilizer because the heads, even tho cut green, are probably full of seed which can grow when the manure is spread upon soil.

Pasture land infested with the Canada thistle is sure to be unevenly grazed. Wherever there is a stalk of the thistle, the grass is left by the livestock, and of course is eaten more closely elsewhere.

The roots do not thrive in sod nearly as well as in broken ground. If the pasture is heavily overgrazed, the thistles may be eaten also, but they are taken unwillingly, and only because they cannot be separated from the grass. This kind of treatment weakens the sod, giving the advantage to the thistle which will quickly take full possession of the land.

NATURAL ENEMIES

FUNGI.—Many parasitic fungi are found on the Canada thistle. One of them, commonly known as the "thistle rust" (*Puccinia suaveolens* Pers.) does more damage to the thistle than all the rest of the fungous diseases combined. Like the other rusts this one has alternate generations, but unlike many of them, both generations are found upon the same plant. This results in a perennial mycelium in the plant, and in the continued production of both kinds of spores, the uredospores and the basidiospores. Early spring infection causes a sudden increase in the rate of growth until the flowers are about to open; then the whole stem withers and dies. The fungus invades and travels along the roots. It sometimes attacks every shoot along a new root with a result that none of the shoots grow into strong or normal appearing plants. The stems die down to the ground level in the fall, but the lower part of the infected underground stem lives over winter. Because of the presence of buds under the scales of the underground stems, shoots from them appear earlier than from healthy roots. The shoots are light green, slender and frail. They grow faster than the other stalks but die just before the flowers open.

As much as 30 percent of a patch can be infested at one time with this disease. It frequently limits the activity of the plant, but does not entirely kill it out. Uredospores are plentiful in pustules on the leaves and stem of the Canada thistle. They produce a second less virulent infection. The third crop of uredospores is often so late that infection from this crop becomes barely visible before the tops are killed by frost. The open pustules give off a characteristic odor which is similar to that of the pistillate flowers of this thistle.

INSECTS.—Of the many insect parasites upon the Canada thistle, only a limited number do any appreciable damage. The Painted Lady butterfly prefers the Canada thistle to any other plant. At times there is so severe an outbreak of this insect that the whole plant is defoliated. If the second crop of larvae are not plentiful,

the new shoots that come up in July and August after defoliation of the first stalks will not be affected and no permanent injury will result. This insect (*Pyrameis cardui*, L.) is characteristically marked with white or yellow spots on the forward parts of its brown wings. The body is 3/5 to 1 inch long and the wing spread is from 2½ to 3 inches. The mature larva is slightly more than an inch long, and has a dull yellow band down the front.

There are two footless grubs which attack the thistle. One of them, the *Dasyneu gibsoni*, Felt., causes one side of the head to break out after the grubs have consumed much of the receptacle and many young seeds. This insect is known as Canada thistle midge. It is closely related to the clover seed midge. The footless grub of a yellow fly damages the heads without any evidence of injury showing on the outside. Most of the seeds in an infested head are destroyed by this insect parasite. Damage done by insects varies much according to the prevalence of the insect.

BIRDS.—One of the most consistent destroyers of the seed of the Canada thistle is the goldfinch. Its diet consists to a remarkable degree of thistle seeds. Some of the seeds are probably uninjured by passage thru the bird, so that eating does not destroy all of the seeds consumed. A large proportion of them, however, are digested. Other birds, most of them closely related to the goldfinch, consume small quantities of thistle seeds.

RUSSIAN KNAPWEED

Russian knapweed (*Centaurea picris, Pallas.*) is not well known generally thruout the United States because of its rather recent introduction, and because as yet it is limited to the parts of the country which have used alfalfa seed imported from Russian Turkestan. This weed is one of several "knapweeds" which are so named because of the heavy gray hair or nap on the stem. This nap is especially noticeable when the plants are young. The plant is called "Russian knapweed" because of the source from which it came into this country.

Its natural enemies have not appeared in numbers sufficient to be of any importance in the control of the weed by destruction of either the tops or the root system.

DESCRIPTION

Russian knapweed may be distinguished from other weeds in Colorado by its characteristic lilac-colored flowers in small round heads, by the tough, dark-brown or black perennial roots, and by the rather shredded appearance of the mature plant when seen alone.

Fig. 9.—A.—The stem, leaves and heads of the mature Russian knapweed.
B.—A leaf of a young plant.
C.—Seeds of the Russian knapweed.

LEAVES AND STEMS—The leaves on a mature stem are small, narrow, with smooth surfaces and edges, and without a pronounced midrib or petiole. The ends of the blade have a rounded point. Short, stiff hairs cover the leaf and stem so that they feel sticky to the touch, and irritate the skin when brushed across the hand or face. The leaves get smaller as they approach the head (See Figure 9-A).

The upper parts of the stems of the mature plants have the same hairy roughness as the leaves. The whole stem is hard and practically inedible when dried in hay. The young stems are covered with a long, soft gray nap which remains upon the lower part of the stem. It does not appear on the branched parts of the flower stalks where the leaves are small. When the nap is removed from the lower part of large stems, a dark-brown or purple color is visible, and continues down to the underground

part of the stem which is much the same color as the true roots that lie horizontally at a short distance below the surface of the soil. The leaves on the upper end of the underground part of the stem are dark, pointed scales, but close to the root these almost disappear and are replaced by fine roots.

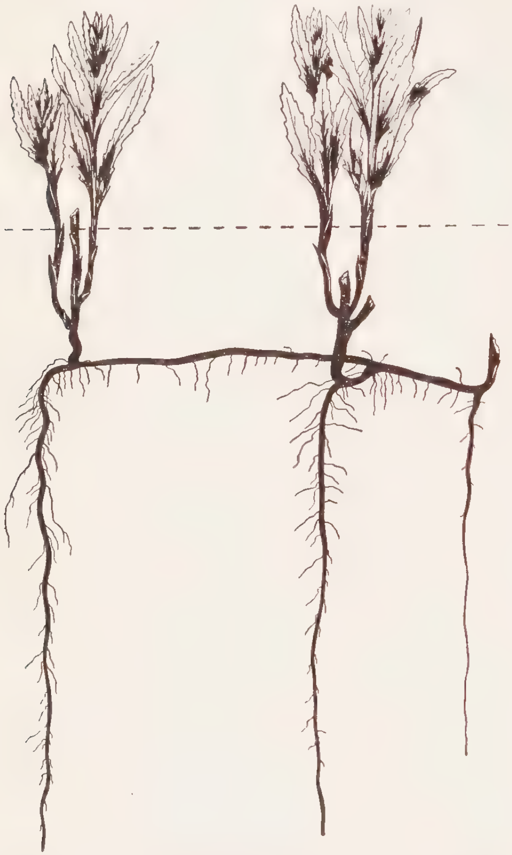


Fig. 10.—A portion of the root system and young shoots of the Russian knapweed.

When the Russian knapweed comes up in the spring the first leaves are large, gray-green and much longer than wide with rounded teeth along the edge of the blade. (Fig. 9-B.) The same long nap that covers the young stem is found upon these young leaves, which are so different from the leaves on the upper part of the stem that one who is unfamiliar with the pest, could easily mistake the young shoots of Russian knapweed for some other kind of plant. Young shoots and their relation to the roots are shown in Figure 10. The young leaves vary greatly in shape, but when the stem is densely pubescent and attached to dark-brown, tough, perennial roots, there is little question that the plant is the Russian knapweed, altho the final proof depends upon the flowers and fruit.

FLOWERS AND FRUIT.—The appearance of small, round, single heads of lilac flowers upon rather long stems, will establish the identity of the Russian knapweed if the leaves, stems and roots leave room for doubt. The heads are never more than 3/8 to 1/2 inch in diameter, and are usually almost spherical. The lack of thorns, and the size of the heads make it possible to distinguish the plant from any thistle. The single heads on long stems furnish an addi-

tional distinction from the Canada thistle. When the flowers are open, they give off a characteristic, rather pleasant odor.

The seeds of Russian knapweed are a chalky light gray, and are marked longitudinally by inconspicuous fine lines. Some of the seeds are slightly curved, altho most of them are wedge-shaped, as is shown in Figure 9-C. Fully developed seeds have been found in all the mature heads of Russian knapweed collected by the writer in Colorado. Seed production by this plant is therefore a very real danger to the localities where this pest is already established.

OCCURRENCE AND HABITS OF GROWTH

Turkestan alfalfa seed imported directly from Russian Turkestan is responsible for the introduction of the pest and for most of the present infestations in Colorado.

ASSOCIATION WITH CROPS.—Up to the present time at least, the Russian knapweed has been or can be associated directly with Turkestan alfalfa seed. When the alfalfa is replaced by a cultivated crop, the pest is discovered often for the first time, growing luxuriantly in patches of almost any size and number. Its similarity to alfalfa in height and the way in which it blends with the leaves, stems and flowers of alfalfa make its detection unlikely by the casual observer of a field, even at close range. Its resistance to cultivation and its capacity to get along with almost any crop makes it as indifferent as the Canada thistle to the kind of crop with which it is growing. When in competition with other weeds in waste places, it can easily hold its own and spread rapidly thru them. Sod seems to have no effect whatever upon the Russian knapweed, for it has been known to spread steadily and rapidly in otherwise good sod pastures where the common wild morning glory was killed out and the Canada thistle was making no headway.

ASSOCIATION WITH SOILS.—The great variety of soils upon which the writer has found rank growths of this weed indicates that there is no soil which is most favorable to its development, unless it be damp clay, where moisture is likely to be abundant, and where the soft earth permits easy penetration of the roots. Equally strong, numerous and menacing infestations have been found on other kinds of soil, but they are not more vigorous, nor do they spread faster than in clay. The slight advantage in clay soil cannot even suggest that the pest is to be more definitely associated with a certain soil than with a certain crop. Its appearance in alfalfa is due to its presence in imported alfalfa seed. The Russian knapweed seems to be able to survive almost any crop in any tillable soil in Colorado.

RANGE

DISTRIBUTION IN COLORADO.—Requests for identification of Russian knapweed and for control measures come to the Experiment Station and the College in increasing numbers. Locations of the numerous infestations known to exist in Colorado are shown on the map in Figure 11. Near Montrose and in the valley of the Gunnison river, Russian knapweed has been found in several places. It is known to be widely distributed over the San Luis Valley. Patches of this pest have been found from the New Mexico line as far north as Hooper and Saguache. A specimen for identification recently came from the San Juan Basin. Knapweed was formerly thought to be limited to the southern and western parts of Colorado because no specimens had been sent from the central and northeastern agricultural regions of the state. During 1927 and the first months of 1928, however, numerous locations have been found in Weld, Larimer and Morgan counties.

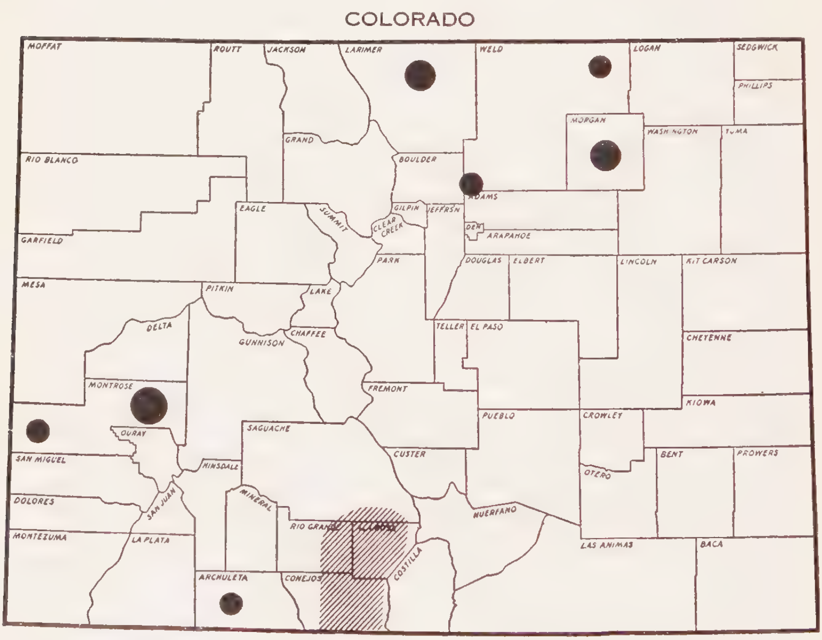


Fig. 11.—Map showing the known distribution of the Russian knapweed in Colorado.

In every case of questions about this pest, alarm has been expressed at its persistence, its capacity to spread and the damage it does to the crops which are planted upon infested land. There is now little doubt about its existence generally over Colorado, and it has been reported from all the states that bound Colorado. Where

imported Turkestan alfalfa seed has been planted there is every reason to believe that infestations of Russian knapweed had a chance to get started because the seed of this pest is almost always present as an impurity. It may have failed in some places to become permanently established, but if alfalfa seed from Turkestan is used repeatedly Russian knapweed is almost certain to take possession of the land upon which it is sowed.

Prevention is far cheaper and better than control or eradication. Only seed that has been cleaned and tested for purity should be used whenever a crop is to be planted.

ROOT SYSTEM

The root system of this pest has never been as carefully investigated as has that of the Canada thistle, but the similarity between the two makes a detailed description of the roots of Russian knapweed unnecessary.

HORIZONTAL ROOTS AND EXTENT OF THE ROOT SYSTEM.—The horizontal roots of Russian knapweed are all of practically the same dark-brown to black color. They are covered by fine absorptive roots which grow out in all directions. The horizontal root is not large except at the rather sharp downward bend where the root expands to be $\frac{1}{4}$ inch or more in diameter. Frequently a number of shoots arise close together along the outside of the bend and grow up into a clump of plants. A vertical root under a group of stems can be easily mistaken for a tap root. Near the bend another root starts a horizontal course for a few feet before it too bends down. In the region where no shoots or bends are found, the fibrous roots are few, but near the shoots the absorptive roots are abundant. The horizontal roots in this plant are shorter than in the Canada thistle. This is probably responsible for the somewhat slower rate of increase in the size of infestations of Russian knapweed when the two plants are under the same conditions.

VERTICAL ROOTS AND DEPTH OF PENETRATION.—Altho the vertical roots of Russian knapweed have numerous large branches, the main root continues in a generally vertical direction with the deviations necessary for an easy path. In one place where the water table was high, the whole root was traced. It was found that it tapered uniformly from the vertical bend to the water line, but did not extend into the water. A number of small branches were sent out horizontally just above the level of the water, probably for the purposes of absorption. Under ordinary circumstances, however, when the water level is low, the roots of the Russian knapweed penetrate into the subsoil and are uniform in size thruout most of their length. The limit of their power to go down into the soil

has not yet been found, but their vigor above ground and resistance below the surface to most treatments are good indications of a deep and extensive root system. A small part of a root system is shown in Figure 10. This pest thrives upon dry as well as irrigated land, so that its root system must be both wide and deep.

SIZE OF THE ROOTS.—So far as the writer is aware, there has been no study of the effects of soil upon the behavior of the roots of Russian knapweed, or of the soils upon the size of the roots. Observations of the sizes of roots of this pest on the Wetern Slope near Montrose, in several places in the San Luis Valley, and in northern Colorado, have failed to indicate any difference between the sizes of the roots in different soils or under different conditions. In all places the diameter of the root at the downward bend was a little more than a quarter of an inch. The thickness of the horizontal root in all cases varied with age, but the maximum was approximately constant. Figure 4-C shows the relative amount of storage region in the root of Russian knapweed, compared with the conducting system. It is plain from Figure 4-B and 4-C that there is a greater reserve region in the roots of the Canada thistle than in those of the knapweed.

This deficiency of storage region in a single root, however, is probably more than balanced by the greater number of roots in the upper layers of the soil, which are sometimes completely matted with the dark-brown roots of Russian knapweed. There is every evidence that the food stored in the roots of this pest is equal in quantity and availability to that of any other plant of the same general nature.

LENGTH OF LIFE OF ROOTS.—The length of life of the roots of the knapweed is not exactly known. Excavations of its roots indicate that the life cycle of this plant is practically the same as that of the Canada thistle. This point, however, will have to be proved by further observation.

NOXIOUS CHARACTERISTICS

Perennial weeds with habits in common have also many similar noxious characteristics.

PERSISTENCE.—The persistence of Russian knapweed has already classed it as one of the most feared weed pests in Colorado, even tho it has been established for a much shorter time than many others. Land that is overrun by the knapweed is useless for all time unless some direct, consistent and effective attack is made upon the pest. It easily survives most methods of cultivation and, if driven from much-used places, takes refuge in out-of-the-way corners.

CAPACITY TO SPREAD.—The capacity of Russian knapweed to spread by natural means is not as great as that of the Canada thistle because of its lack of a distributing device, but this disadvantage is more than made up by the vitality of the roots and their capacity to form new plants.

There are many fields in Colorado infested with Russian knapweed in which the small infestations over the field are definite proof that some operation of cultivation or preparation of the land reached the roots and dragged fragments of them into new locations. The vitality of these fragments is one of the greatest sources of danger in the spread of the knapweed over a field. The natural increase of a single infestation is great enough without the sudden appearance of new patches caused by the dragging of roots when the soil is plowed, harrowed or floated.

Impure Turkestan alfalfa seed has been responsible for the introduction of this pest into Colorado and many parts of the United States. Uncleaned grains from fields in which the knapweed is growing, or irrigation water which carries the seed, are constant menaces to weed-free land. Because seeds cannot be windblown for any distance, artificial means of dissemination are the chief causes of new infestations, and because these artificial means of dissemination can be entirely controlled, the spread of Russian knapweed in impure seed seems to be utterly inexcusable.

In March, 1928, there was released from the Denver Customhouse approximately 50,000 pounds of Turkestan alfalfa seed, imported from Russia. About 25,000,000 seeds of Russian knapweed were brought in with this alfalfa seed. This is enough to produce a perfect stand on at least 5,000 acres of land. Ten percent of the shipment was stained red to indicate that it was a variety of alfalfa not adapted generally to the conditions of the United States. Much of this alfalfa seed was not sold during 1928, and will be on the market in succeeding years. Anyone who intends to use Turkestan alfalfa seed, should look at large samples to learn if part of it has been stained red. In that case every prospective purchaser should examine closely a considerable quantity of it on paper for conspicuous, light-grey, wedge-shaped seeds. Whether or not any are found, before the seed is planted a 4-ounce sample should be sent to the Colorado Seed Laboratory at Fort Collins, for a test of its purity. If any seed of Russian knapweed is found, the alfalfa should NOT be planted. This weed is so serious a menace that no precautionary measure is too great to take, in order to protect weed-free land from infestation by one of Colorado's most noxious weed immigrants.

Fresh manure from animals that have been fed hay or grain containing seed of the knapweed, or bedding that has in it the

mature heads of the pest, contains viable seeds of the weed. It will increase the damage already done by the pest if the fresh manure is placed upon the soil. Dangers of this kind have already been discussed under the Canada thistle and prevention measures are suggested later in the bulletin.

DENSITY OF GROWTH.—When the knapweed grows unmolested, it makes a perfect soil cover and eliminates all other vegetation. Even when controlled in part by cultivation, there is a constant battle between the farmer and crop on one side, and the weed on the other, in which the weed often gains the victory. The Russian knapweed's combination of persistence and density of growth makes it one of the most noxious weeds in the state.

PRESENCE IN HAY AND PASTURE.—The stiff stems and rough leaves of the knapweed are almost inedible when dry. The presence of much of the pest in hay seriously decreases the feeding value of the hay and lowers the market price. As well as being inedible, it menaces the land of every purchaser. Hay that contains Russian knapweed should not be salable, because of the danger of spreading the weed by seed in the hay.

Pastures infested with the knapweed cannot carry the regular grazing load because it is not eaten freely even when green, and it chokes out desirable forage plants as fast as it spreads. Because of its close association with alfalfa, and its capacity to make pastures almost useless, it is particularly serious in alfalfa fields and pasture lands where grazing is heavy.

PREVENTION, CONTROL AND ERADICATION OF PERENNIAL WEEDS, SUCH AS CANADA THISTLE AND RUSSIAN KNAPWEED

The following discussion of methods of prevention, control and eradication of perennial weeds is general, but the Canada thistle is mentioned more frequently because of extensive work that has been done upon it.

Whenever work is done on weeds, it should be with the purpose of ultimate extermination of the plant attacked. There are three ways in which weeds may be handled; by the prevention of infestations, by the proper control of existing patches, and by the complete eradication of the pest. The best way is to keep the land free from weeds by consistent and vigorous prevention measures. They may seem useless, expensive, irksome and without result, but they are cheaper and far less annoying than the attention demanded by control or eradication measures for weeds.

Control of weeds is largely a matter of sanitation which prevents the spread of the pest into other places, and the rapid increase in size of the already-existing infestation. Methods of eradication frequently differ from those used for control, more in degree or intensity of application than they do in the principles upon which their successful use is based.

The first of these, prevention, must be practiced constantly; and the second, control, is to be considered as a prevention measure until the time comes when extermination is practicable.

PREVENTION MEASURES

The most satisfactory of all control measures for any pest is the prevention of infestation. Study of the habits, life history and general characteristics of a plant help to determine the most economical and effective means of control, and give the best ways for keeping a region free from a weed.

CLEAN SEED.—The cheapest and most effective means of protection from any noxious weed is the use of clean seed. It is unnecessary for anyone in Colorado to plant any kind of impure seed, for the State Seed Laboratory at the Agricultural College is equipped to analyze seed samples and to identify impurities in them. Any seed that contains thistle or knapweed, should be rejected by the purchaser, and pure seed obtained from a dependable source.

Along with the use of clean seed goes the need for care in cleaning farm machinery when it is to be moved from place to place. Many kinds of seed are known to have been carried from one farm to another in the dried mud on machinery. During harvest the seeds rattle out of the bundles of grain, collect on the racks, or in

the thresher and are carried to new locations. Combines usually carry a load of weed seed from one job to another, and scatter some all along the way. Protection from infestations due to this kind of spread is easy, simple and many times worth the inconvenience caused by a few minutes delay that is necessitated in the cleaning of the wagons, sieves and other parts where weed seeds are likely to collect.

CLEAN HAY AND MANURE.—Hay meadows or fields of alfalfa infested with Canada thistle or Russian knapweed are likely to be sources of mature seeds when the hay is made. If much Canada thistle is in the hay, it is unfit for feeding and the seeds go wherever the hay is taken. The stiff stalks and rough leaves of the Russian knapweed together with its seed heads make it a useless and dangerous impurity in hay. The hay is eventually returned to the soil and with it goes the seed of these pests.

If manure is known to contain seeds of the Canada thistle or Russian knapweed, it is necessary to leave it piled for a season so that decomposition will kill many of the weed seeds, and decrease the danger of infestation when the manure is applied to the land.

PREVENTION OF SEED FORMATION.—Once a place becomes infested with the Canada thistle or Russian knapweed, it is possible to check their spread by prevention of the formation of seed. This can be effectively done by cutting the stalks two or three times a year. If it is impracticable to cut them, spray poisons can be used when directions given on the container are followed carefully, and when proper precautions are taken to keep poisonous materials from injuring livestock.

Roadside weeds are often considered to be the business of the state, county or township, and not the concern of the person whose land lies along the road. When these weeds are noxious and endanger farm land, it is to the interest of all to prevent the formation of seed. In case the Canada thistle or Russian knapweed produces viable seeds along roadways or irrigation ditches the farmers must cut the plants down in self protection. The damage done in pastures or in waste places may not justify the expenditure necessary for eradication of these pests, but if they are a source of new infestations, nothing should be left undone to prevent the formation and dissemination of seed.

CONTROL MEASURES

Practices which result in prevention of new infestations, also tend to hold down the existing patches of perennial weeds.

CUTTING TO PREVENT SEED FORMATION.—The cutting of the stems to prevent the maturation of seed also tends to hinder the

development of the plant, as well as to prevent new infestations. When reseeding is stopped, control of existing patches is much easier than when the plant is continuously renewed by seedlings.

Burning Dried Plants After Cutting.—Many times there are mature seeds on plants when they are cut, or the seeds mature after cutting. As soon as they will burn, it is well to destroy the dried plants by fire before the seeds are shattered out and fall to the ground. Fire does not kill all the seeds unless the heads are completely burned, but a good heating injures them so that the danger of reinfestation from seeds is decreased.

Sprays as a Substitute for Cutting.—Many places where the Canada thistle or knapweeds are growing cannot be cut over because of the nature of the ground. The development of tops is often just as good, and the production of seed is just as plentiful there as on cultivated soil or on places that can be mowed. Spray poisons which kill the tops fill a distinct need in such places, when temporary elimination of the tops is desired.

Many patent sprays are on the market for which great herbicidal powers are claimed. They have been found to be useful in other places and may prove to be useful in Colorado, although experiments to date are not conclusive. Most of them, however, are useful for killing the tops of perennial weeds. Sometimes with sufficiently frequent applications of these poisons, and with especially favorable conditions, an eradication of a perennial weed is possible.

Separate Cultivation of Infestations.—If the area infested with the thistle or knapweed is small, rigorous eradication measures are better than contentment with merely keeping the patch from spreading too rapidly, or being spread by careless cultural methods. When the infestation has reached a considerable size, the safest means of control is a practice that amounts to a quarantine. All machinery used to cultivate or work in land infested with perennial weeds should be cleaned thoroly before it is used elsewhere. It is essential that infestations receive separate treatment. Plowing, harrowing, floating or cultivation continuously from infested to weed-free soil should never be permitted. Sometimes the nature of the crop raised upon infested land neither lends itself to clean cultivation during any or all of the season, nor does it sufficiently shade the ground to smother out perennial weeds. This is especially true of the small grains and of corn. Infestations of any size in corn require much attention and hand labor.

In many cases, therefore, it seems more profitable to employ summer fallow for a season or two in order to get the upper hand

of the Canada thistle and Russian knapweed. One season of fallow will not kill these pests, but it will weaken them enough to make it possible to grow a paying crop upon the land the succeeding years. A single year of fallow is valuable in other ways, because it eliminates many of the annual weeds whose seeds have accumulated in the soil. They are caused to germinate and are destroyed by the stirring of the soil.

CROP ROTATION.—The presence of weeds of any kind upon a farm depends to a great extent upon the management of the land. Probably the largest factor in management of the land is the succession of crops. Soil infested with the Canada thistle or Russian knapweed can be freed from them by use of the proper methods of starvation with which may be combined a wise rotation of crops. If fallow cannot be practiced until the perennial pest is dead, the use of a crop-rotation system is essential, because the succession of crops has different effect upon perennial weeds and tends to keep them from becoming too vigorous.

In each locality and under each type of farming, there is a group of crops which can be used to keep the pest in its weakened state until a new direct attack can be made upon the reserve regions of the plant. No one system of crop rotation can be recommended because of the varying conditions in Colorado. In irrigated regions the use of cultivated crops alternated with smother crops is to be preferred to a rotation system that includes small grains, for in small grains the thistle or knapweed can recover in one year from the damage done in several years of clean cultivation, fallow, pasture or smother crops. If grains must be grown on land where perennial weeds are found, the land should be fallowed until late fall, and the crop sowed as late in the spring as is consistent with proper harvest. This is to destroy all the fall growth and to cut off shoots that have been pushing their way up thru the frozen ground during the winter.

Destruction of the early spring shoots gives spring grain a more nearly even start with these weeds and the rapid growth in May and June easily keeps up with their increase in size during these months. Seed production should be controlled in the grain fields by either cutting down the flowering stalks or by pulling them out by hand.

SMOTHER CROPS.—All of the cultivation methods for controlling the perennial weeds involve the expenditure of much labor. When this can be replaced even in part by equally effective methods which make use of the ability of some plants to shade and crowd out others, the time and effort necessary for cultivation of perennial weeds can be diverted to more immediately productive operations.

PASTURE.—It has already been developed that there is little permanent damage done to the Canada thistle or knapweed by pasturing. A good heavy sod checks spreading; the leaves of the very young plants are eaten freely by sheep and goats early in the spring when other forage is scarce, but little damage is done by animals. Trampling breaks the stems but unless they are completely broken off, new shoots do not form upon the roots. Furthermore, it is always necessary to cut the stems at the time of flowering to prevent the formation of seed. Of all the control measures recommended, this is the least effective for Canada thistle and Russian knapweed, but it is one of the best for the common wild morning-glory and other bindweeds.

ERADICATION MEASURES

GENERAL PRINCIPLES AND METHODS.—Any attempt to eradicate a perennial weed must be in accordance with the principles upon which effective treatments are based. Almost all operations which result in the death of perennial weed pests either starve the roots by using up the stored food, kill the tops and underground portions outright, or destroy the roots so that the tops also die. The discussion of the principles of eradication is followed by specific information and recommendations for eradication of both small and large areas.

STARVATION OF THE ROOTS.—Starvation of the roots results when the tops are not permitted to develop normally and to expose a large leaf surface for the manufacture of food. When for any reason the food-making organs fail, the new shoots draw upon the stored material in the reserve region of the roots. Energy is consumed in the growth of the shoot at the same time that the root is furnishing structural material for the new stalk. If the new parts reach the surface and develop normally, the food used in the regeneration is quickly replaced. On the other hand, if, instead of natural development, there is a continuous destruction of new shoots as fast as they reach the surface of the soil, there is a constant drain upon the reserve supply. This supply may be, and frequently is an exceedingly large proportion of the root, but it is not unlimited. If the reserve is used continuously without a chance being given for replacement, the time is certain to come when there is no more food in the roots to supply material or energy for the formation and growth of stems from the buds on the roots of perennial weeds. When the whole plant has been exhausted, the starvation process has been completed, and the infestation has been exterminated. This is a slow process for many plants, and a tedious one for the person who has to keep the tops from growing, even for a short time in sunlight and air. This means, however, has been found

by long and wide experience to be based upon the most practical, economical and even profitable principle when the proper eradication measures are used.

Operations which result in the starvation of the roots can be classed under clean cultivation or fallow, and "smothering." The smothering may be practiced either by the use of a plant which grows more vigorously than the weed pest to be eradicated, or by the use of dead material for shutting off light and air from the plant. The mechanical means usually consist of straw, manure or stack bottoms, or it may be heavy paper or sheet metal which stop the light as effectively as a thick layer of straw and offer more resistance to upward growth of stems and shoots than does loose material piled upon a patch of Canada thistle or Russian knapweed.

CLEAN CULTIVATION AND FALLOW.—This method has already been discussed under "control methods" where the principle of partial starvation is a control measure. If eradication is the aim, it is necessary that cultivation be clean and that the fallow be one that keeps down all growth. Clean cultivation in this sense means nothing less than cultivation which keeps any plant, other than the crop plant, from putting forth green leaves. If no crop is being raised upon the land and the condition is that of fallow, there must be enough disturbing of the surface of the soil to destroy all the shoots that come up from the perennial storehouse of food and energy. This probably will mean several times as many cultivations as are necessary for the extermination of annual weeds. The cultivation should be deep enough to cut off the new shoots at their base, but not deep enough to reach the horizontal roots. The cultivations must be repeated as often as it is found that shoots are about to push thru into the sunlight. This may mean as many as 20 cultivations a year for 2 years. From the nature of the Canada thistle and Russian knapweed, 2 years of cultivation should be enough to use up all the reserve of food and to practically eliminate the pests. For other perennial weeds whose roots live indefinitely, 2 years of clean cultivation or fallow may not exhaust the reserve supply of food.

SPRAYS AS A SUBSTITUTE FOR CULTIVATION OR FALLOW.—The most constant demand from the people who are troubled with perennial weeds is for a spray which will kill the pests with one application. As yet a spray has not been found that will work this way for perennial weeds under the conditions of Colorado. This does not mean that sprays do not injure weeds when they are applied to the aerial parts. It does mean, however, that with many of the sprays, perennial weeds suffer no more from a spraying than they

do from a single cultivation. If cultivation is impossible in locations where eradication is necessary, the roots can be starved by repeated applications of poisonous sprays. One must not become discouraged any sooner, nor be any less punctual in the application of sprays, than he is with cultivation practices for starvation. The effects of the spray materials are as variable as the costs, altho the effects are not necessarily in proportion to the cost of the material used. For the control of perennial weeds, most sprays are to be considered as an accessory to the less expensive cultivation methods.

SMOTHERING.—Smothering is usually thought of as elimination of air with eventual loss of life by suffocation. As it is used in this bulletin, the word "smothering" has something of this idea, but more of the idea of crowding a plant out of its room for growth, and the shutting off of light from the leaves. No plants keep air away from others to such an extent that the "smothered" plants cannot live; they effectively choke the plants by shading. This is the true conception that should be held of the "smother crop," and there should be a distinction made between the effect of choking out by shading a plant, and the smothering of one that is kept under the surface and has its air supply cut off at least in part and its light entirely absorbed by material that has been placed upon the infestation.

SMOTHER CROPS.—The nature and kind of smother crops that assist in the eradication of the Canada thistle, Russian knapweed or any other kind of perennial weed is varied. If the smother crop is sufficiently dense, tall and persistent, an open soil surface that is perfectly shaded is helpful because the crowding at higher levels is close enough to keep the stems from pushing up to the life-giving sunlight. Smother crops should of course be of value for other purposes and should be easy to remove from the land once their intended purpose is accomplished.

Smother crops must have the capacity to make a quick, dense growth, and to hold their own against the invader which they have been planted to suppress.

There are two kinds of smother crops; perennial plants, and annuals that are planted each spring after the pest has been kept under the ground by cultivation for a part of the season. Either the perennials or the annuals are effective if conditions are favorable. The perennials must come up as early or earlier than the Canada thistle or the Russian knapweed, if they are to be effective as smother crops. They must make a more rapid and dense growth during the months of May, June and July, and they must retain their vigor until frost, if they are to compete successfully with these plants.

If the smother crop is to be cut during the summer, it must be able to recover more quickly than the perennial weed and to keep the new shoots of the pests in the shade. Alfalfa has been found in many states to be a successful crop for controlling these and many other perennial weeds. It has the advantage of rapid growth, dense stand and quick recovery after cutting. One disadvantage is its limited height, which is naturally exceeded by some growths of the Canada thistle, and by the normal growth of Russian knapweed. It is rather frequently winter killed also, and dies out from other causes more easily than do the weeds it is expected to control. Biennial sweet clover grows taller, makes as dense a soil cover, and can be left to grow a whole season without losing density or vigor because of seed production. In general where good stands of the white sweet clover can be obtained, it is superior as a smother crop to the other clovers, or to alfalfa. It should be reseeded the fall of the first season it has made growth, so that there will always be a heavy stand of young plants close to the soil. The reseeding from the old plants will automatically take place the fall of the second year.

Altho alfalfa, sweet clover or similar smother crops with rank top growth hold the Canada thistle and Russian knapweed well under control, the roots of the smother crops do not seriously conflict with those of the Canada thistle or plants with similar root systems. Both have long vertical roots, but neither of them can be considered to be sod-forming plants. Such plants as do form a firm sod, however, impede the progress of the horizontal roots of the thistle or knapweed, but do not as a rule grow tall enough to shade the stems. Many of the horizontal roots of these two plants grow too far below the surface of the soil to encounter the mat of grass roots. The shoots, however, have difficulty at times in penetrating sod, which is therefore to be considered as a useful means of slowing up the progress of these pests but not an effective one for permanently weakening them.

In places where the growing conditions for annual crops are reasonably certain, or where crops can be controlled by irrigation, the use of a smother crop for the growing season, accompanied by mechanical means of control for the rest of the year has proved successful. Quick-growing, early maturing plants such as millet, cane or sorghum, when sowed heavily, after a fallow during April and May, will set perennial weeds back as much as a summer of intensive cultivation and will yield a profitable crop at the same time. In many ways these summer smother crops are more dependable than the perennial smother crops, because the time for their growth, and the condition of the pest when they are growing can be

more nearly controlled. Cane, sorghum or millet is recommended in Kansas for this purpose.

Another kind of annual smother crop that has been used extensively in northern Iowa and southern Minnesota for both the control and eradication of the Canada thistle, is the sugar beet which requires almost constant cultivation of the soil until the tops practically cover the ground and allow little light to filter thru the leaves. The leaves usually stand up some distance above the crown of the beet, so that it is necessary for any plant that comes up from below to make a great growth in length before it reaches sunlight. This combination of cultivation and smothering has been found to be one of the most successful control measures for the Canada thistle in the North Central states. Beans which are raised in quantities on the drylands of Colorado, can be used in much the same way as beets for the controlling of perennial weeds where irrigation water is not available. Beans require much cultivation while they are young and cover the soil well when cultivation ceases. These two crops are among the most profitable that can be raised. The increase in yield due to the cultivation necessary for the control of the perennial weeds almost always pays for the labor of control.

SMOTHERING BY COVERING THE PLOTS WITH DEAD MATERIAL.—Many attempts to kill out perennial weeds have been made by piling straw upon the place where the weeds are growing. Some of these treatments have been successful, but most of them have failed for the two following reasons: In the first place straw settles a great deal after it has been handled. The much thinner layer of straw after several weeks of standing allows the shoots to come thru to sunlight and air. The edge of the pile of straw must be 8 to 10 feet beyond the plants farthest from the center of the infestation because normal spreading by roots is not stopped by smothering. Straw is therefore ineffective when it is used in insufficient quantities.

In the second place dry smothering agents of this kind have no injurious effect upon the shoots as they come thru it. The straw acts like a very light soil which has no other influence upon the shoot than to force it to grow farther to light. Wet straw, on the other hand, will begin to decompose, and will sometimes become so warm that ordinary plants cannot live in it. Real damage is then done to the pests covered with this kind of a smother material. The principle of smothering with straw is correct; it is a question mostly of the quantity that is used, and the condition when applied.

There is no essential difference in the use of manure, straw or stack bottoms for smothering out patches of the Canada thistle or Russian knapweed. Manure is usually moist and does not settle as much as straw. It is full of organisms that cause the manure to

heat and to injure tender sprouts from the roots. As a general rule when manure is applied so that the fully settled pile is 6 feet thick and the area covered from 16 to 20 feet greater in diameter than the infestation there is little question as to the result. To be sure that none of the shoots of the Canada thistle or Russian knapweed can penetrate the manure, it is necessary to have the pile at least 6 feet deep for 3 years. After that, if no shoots are found creeping out from around the edges of the pile the manure can be safely removed.

Stack bottoms have the same virtue as manure, in that they are often wet, and already in the process of decomposition. The essentials for the use of vegetable materials as smothering agents for killing perennial weeds are that they be deep, wet and in the process of decomposition. Under these conditions, heat is generated, and the air is at least partly excluded from the solid mass of smothering agent and from the soil below.

There have been reports of successful eradication of the Canada thistle by covering the patch with sheet metal, often corrugated iron from an old building, and leaving it upon the patch for several years. This makes a covering that is light-proof and resistant to plant growth.

Heavy paper, usually tar paper, is recommended as a covering material for small patches. It acts in the same way as sheet metal, but has the disadvantage of being fragile and easily broken by an animal's foot, or any hard object that might fall upon it, so that it is almost essential to fence in well an infestation that is covered with paper. The expense of this method and of these materials practically prohibits their use.

DIRECT KILLING.—The other principle upon which perennial weeds are eradicated is that of a direct kill with a limited number of operations such as spraying, digging or treatment with carbon disulfide. It is obvious that the tops and the roots must be eleminated at the same time.

In other states, one application of a spray poison has been known to completely kill Canada thistles and other perennial weeds. In general, this is an exceptional case, for several treatments even, are recommended by the manufacturers of commercial sprays. During the last 3 years, the writer has not succeeded in killing anything but the tops of perennial weeds when using a number of typical arsenical sprays.

Altho the removal of a whole plant of the Canada thistle or Russian knapweed involves much labor, a sure way to kill perennial weeds directly is to dig out the whole plant, and destroy the roots. It is usually necessary to remove the roots to a depth of 3 to 4 feet

below the surface, being careful that all of the roots are taken from the soil when dug, and that none get put back into the excavation, because a small section of a root can render the whole operation useless if it is allowed to grow unmolested. Digging is practicable only where seedlings or isolated plants from fragments of roots are starting a new infestation.

Soil poisons have been used for many years in the disinfection for insects, and at times roots of plants were killed by the disinfecting agent. The use of carbon disulfide for killing the roots of perennial weeds has become rather general in Idaho, and has been found to be successful in tests in California and Colorado. Its value has not been established for all locations in this state, altho hopeful results were obtained during the summer of 1927 and 1928. The best results have been obtained in rather dry soil. The holes were placed at 2-foot intervals in rows 21 inches apart. The alternate rows of holes were staggered to make equal-sided triangles. Two ounces of carbon disulfide were placed in each hole, and the openings closed with dirt which was well tamped to prevent loss of the gas by evaporation. The killing may take place in a few hours after application, or be delayed for some time, according to the condition of the soil, and the soil is free from all traces of the poison within a month after treatment. There seems to be no particular season that is best for the application, excepting in so far as the amount of moisture in the soil is governed by the season. Penetration is faster at a higher temperature and in a drier soil.

Other soil poisons have been found to be effective, but the difficulty of application, or the dangerous nature of the materials makes them less desirable and more expensive to use.

Soil poisons are not specific for any kind of plant or animal. They kill most of the life that is in the soil if they come in contact with it. Very large woody roots are an exception.

Large quantities of salt spread upon the soil will kill any plant. Its action, which is one of drying out of the roots as well as poisoning them, is rather slow, and the effects upon the soil are bad. Experience has shown that at least 2 pounds of salt per square foot must be applied to assure a kill. This means 87,120 pounds or practically 44 tons of salt per acre. Ice-cream salt is both the cheapest and the most effective. A bottom price for it in Colorado can be considered to be $10 per ton. At $440.00 per acre, the use of this material is prohibited by cost for anything but small patches. Furthermore, except where the salt can be washed out by flooding, permanent damage is done to the soil; in some cases the soil is rendered useless for cultivation for many years. This kind of treatment is not to be recommended except on places where other

means would be impractical, and where sterility of the soil is not important.

ERADICATION OF SMALL AREAS.—The size of the infestation modifies only the method of treatment, and not the principles of eradication. Practices which will eradicate a small area will be equally effective upon large ones. Those recommended for small areas are not necessarily the best for large areas because of economic reasons, but they are practical because of their effectiveness and the protection they afford to the weed-free land about the pests. Additional information on eradication measures for small areas is given below.

Patches less than 2 square yards in extent can be dug in a short time. An 18- or 20-inch spade will turn up practically all of the horizontal roots of the Canada thistle or Russian knapweed. If the infestation is old, a second layer should be removed. When only one layer is taken out, shoots are likely to reappear from the ends of the vertical roots after several weeks. It will be necessary to starve these roots by digging out the sprouts as they are found.

Special, machine-cultivation of small patches of perennial weeds is usually impractical. If the areas are of moderate size, hoeing, or hand driven cultivators will bring about the desired results.

Small infestations of the Canada thistle or Russian knapweed are likely to start up in the feedlots on a farmstead. The easiest and most certain eradication measure in such a place is the use of salt, which may be applied either as brine or in the form of ice-cream salt. If the latter is used, care must be taken that poultry cannot pick it up, for a few chunks of salt are fatal to fowls.

When small patches of a perennial weed in a field are to be eradicated to protect the whole field, carbon disulfide is a quick, effective and economical means of eradication. The cost of treatment may be $1.50 or more per square rod for material and labor, but under favorable soil conditions results are immediate and permanent.

Sprays can be used upon small areas as economically as upon large ones. Care must always be taken to follow exactly the directions printed upon the container and to keep all of the spray material, whether dilute or concentrated, from getting into the mouth or eyes. When any of it comes in contact with the skin it should be washed off with plenty of water as soon as possible. Generous applications of linseed oil to the hands will protect the skin, and make easier the removal of the poison with water.

Smother crops are as useful on a small area as on a large one but are generally not economical. Other and better means of eradi-

cation are available for isolated patches. If, however, there are numerous small infestations spread about over a field, so that it must be treated as a unit, smother crops are the most effective and economical means of eradication that can be employed in the extermination of the thistle or knapweed.

It is only for relatively small infestations that the use of dead material for smothering out the Canada thistle or Russian knapweed is practicable. In the first place, supplies of the smothering materials are usually limited and in the second place the labor of moving enough of it to cover even half an acre to a depth of 10 feet with straw or manure is too great to be profitable when compared with the labor of clean cultivation or fallow. Then too, all the smothering material must be removed after the roots have been starved. Use of sheet metal or paper to kill the pests is prohibited by the price for anything but the smallest patches. Except for very small patches, or those inconveniently located, mechanical means or competition with other plants is to be preferred to the attempt to smother out the thistle or knapweed by covering them up.

ERADICATION OF LARGE AREAS.—Altho the expense connected with the extermination of large areas is greater than that involved in the eradication of small ones, the cost per unit can be much less because of the extensiveness of the operations.

Indirect methods of killing large areas of any perennial weed have been found to be the most practical and economical means in many places, especially those where smother crops cannot be depended upon to grow vigorously because of lack of water. *Clean fallow* during the growing season, like clean cultivation, requires more work than ordinary practices of farming because the stems of the thistle or other weed of this kind must be kept from forming green leaves even for a short time, or all the previous work is lost. Two years of clean fallow or cultivation will usually kill the roots of the Canada thistle, and probably the Russian knapweed, altho there have been no definite experiments completed on the latter weed in Colorado. This time limit cannot always be depended upon, and a third season should be allowed for cultivation, or a heavy smother crop should be planted. After this the patch should be watched closely for stray surviving plants which must be dug out completely whenever they are found.

The advantage of fallow for weed control and eradication is largely one of convenience. When fallow is not necessary for other reasons, the same labor on the land can be expended in clean cultivation of a crop which is as effective as fallow in the eradication of the Canada thistle, Russian knapweed and most other perennial

weeds. Like fallow this practice must be continuous thruout the growing season of the thistle or knapweed.

For large infestations there is no more convenient means of starvation of the roots than the use of a dense soil cover that can keep well ahead of the development of the Canada thistle or Russian knapweed. Recommendation of specific smother crops is difficult because of the difference in their behavior under varying conditions. On dryland, after two summers of clean fallow, a heavy stand of cane or millet should be easy to obtain, and it should complete the starvation of the roots of perennial weeds. Perennial crops which cannot be irrigated are likely to be ineffective for smothering out perennial weeds because they cannot produce a dense, rank growth season after season. On irrigated land, however, where growing conditions are largely under control the choice of smother crops can fall upon those that are most convenient and profitable.

Altho crop rotation is usually considered to be more of a control than an eradication measure, reports of killing perennial weeds by crop rotation are numerous. No generally useful recommendation can be made excepting that the systems always make use of a succession of cultivated and smother crops.

In any practice for the prevention, control, or eradication of perennials, the price of freedom from weed pests is ETERNAL VIGILANCE.

Bulletin 349 November, 1929

EFFECT OF LUMNITE CEMENT AND PLASTER OF PARIS CAPS ON STRENGTH OF CONCRETE TEST CYLINDERS

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EFFECT OF LUMNITE CEMENT AND PLASTER OF PARIS CAPS ON STRENGTH OF CONCRETE TEST CYLINDERS

By Don J. Tripp, Testing Engineer

For the last 8 or 9 years, thru a cooperative agreement, the Road Materials Laboratory of the Colorado Agricultural College has been testing the field cylinders of the Colorado State Highway Department. Because of the difficulty and time required for capping the cylinders in the field, these cylinders come to the laboratory uncapped and are usually about 10 days old. It is necessary to cap these cylinders before testing them and it is our regular procedure to cap them with lumnite cement mortar. This method requires 2 days, 1 day to thoroly wet the cylinders and the other for the caps to harden. The cylinders sometimes reach the laboratory with less time than this remaining before being tested and when this is the case we use plaster of paris caps, which require only 15 or 20 minutes to harden.

To determine whether or not our methods of capping were satisfactory, it was thought advisable to run a short series of tests to determine what effect the different caps had on the compressive strength of the specimens. This was particularly true of the lumnite cap which has been the subject of some criticism.

It was thought that rather than make experiments covering all conditions it would be better to experiment with extreme conditions only, and if the methods of capping were satisfactory for these conditions, they would certainly be satisfactory for intermediate conditions. Accordingly, only two different mixes were used. One, a mix giving concrete of a strength of about 1800 pounds per square inch at 28 days, was proportioned 1:4.57:5.55 by weight. The other, which made a concrete of approximately 4800 pounds strength per square inch at 28 days, was proportioned of 1:1.97:2.89 by weight. The water-cement ratio used in the first mix was 1.15 and in the second, 0.70. The low-strength cylinders were tested only at 28 days but the high-strength cylinders were tested both at 7 and 28 days. In this way we experimented with high- and low-strength cylinders and with cylinders tested at the two ages of 7 and 28 days. We also made some of the cylinders with rough ends and some with relatively smooth ends.

It is desired to acknowledge the helpful assistance given by Fred A. Riddell and Ira R. Rubottom, former laboratory assistants who assisted in making the tests.

Materials and Making of Test Specimens

The following materials were used in making the concrete test cylinders:

The cement used was a portland cement manufactured by the Boettcher Plant of the Colorado Portland Cement Company. That this cement is stronger than the average portland cement is shown by the high strengths obtained in the following tests.

The sand used was a granitic river sand, of hard angular particles which had the following grading:

Passing 4-mesh sieve	100.0 percent
Passing 8-mesh sieve	83.3 percent
Passing 14-mesh sieve	64.4 percent
Passing 28-mesh sieve	34.3 percent
Passing 48-mesh sieve	13.8 percent
Passing 100-mesh sieve	4.2 percent
Silt by eleutriation	1.0 percent

The gravel used was hard granitic river gravel, partly crushed, which had the following grading:

Passing 1½-inch screen	100.0 percent
Passing ¾-inch screen	51.2 percent
Passing ⅜-inch screen	20.5 percent
Passing 4-mesh sieve	0.0 percent

In order to assure the same grading of sand and gravel in each batch of concrete, the sand was split into two parts, and the gravel into three parts by hand sieving. These parts were recombined in each batch to give as nearly the original gradings as possible.

The concrete was mixed by hand in batches large enough to fill five 6- by 12-inch steel cylinder molds; and ordinarily not more than 2 batches were mixed in 1 day. The molds were filled in the regular way, which is to rod each third as it is placed in the mold, except that to eliminate the variation due to imperfect cylinders, each third was rodded more than the customary 25 times. This partly accounts for the high strengths obtained. Figure 1 shows the cylinder molds ready for filling.

The day after the cylinders were molded they were removed from the molds and stored in water until the day before they were to be tested. At this time they were removed from the water and capped as will be described later. After capping they were covered with wet burlap until just before they were to be tested.

Of the 5 cylinders made from each batch, 1 was capped shortly after molding with what we term a standard cap. This method of capping will be described later. Two of the remaining 4 were left with what we call ordinary ends. These ends were produced by molding the cylinders on a piece of unplaned lumber and striking the tops off with a straight edge. The ends of the other 2 cylinders were left extremely rough. The lower ends

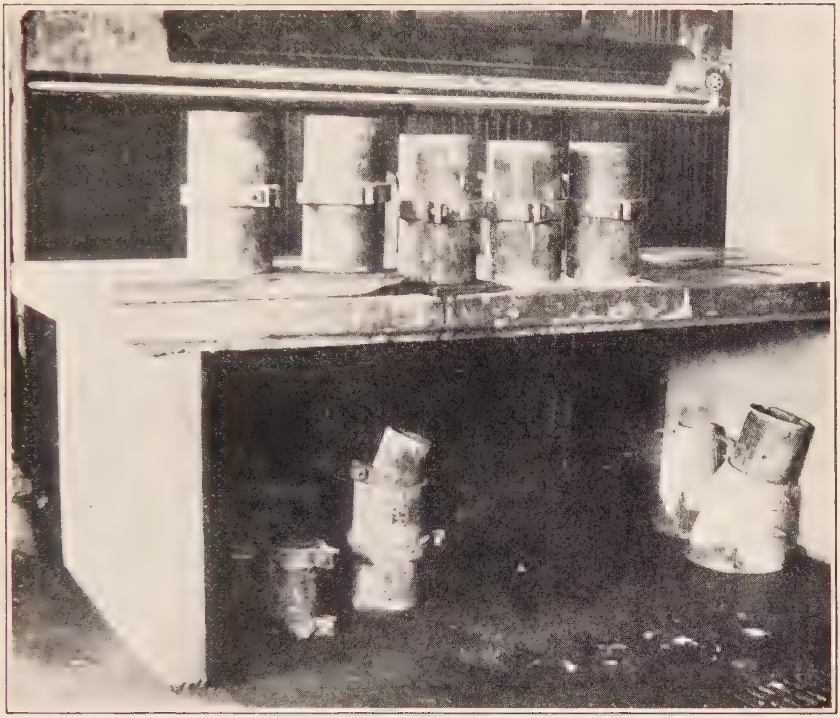

Fig. 1.—Cylinder molds ready for filling. Notice that the two on the left have been placed on unplaned lumber, the two on the right on rough plaster of paris bases and the center one has been set on a machined steel plate.

were made rough by molding the cylinders on roughened bases of plaster of paris, 2 of which are shown in Figure 2, and upper ends were made as rough as possible with a trowel.

Figure 3 shows the 5 cylinder molds after all have been filled and the standard cap has been applied to the center cylinder. The 2 cylinders on the left are the 2 with ordinary ends and the 2 on the right are those with rough ends. Figure 4 shows the end conditions obtained on the 5 cylinders. The lower ends of the 2 outside cylinders have been turned up to show the end conditions obtained with the unplaned lumber and the plaster of paris bases.

Apparatus and Methods of Capping

On the day before the cylinders were to be tested, all of them, including the cylinder already capped with the standard cap, were removed from the water. To each end of 1 rough-ended cylinder and 1 cylinder with ordinary ends, plaster of paris caps were applied. The 2 other uncapped cylinders were capped in the same way with the lumnite cap. The apparatus used in

applying these caps and obtaining square ends on the test specimens is shown in Figure 5. Figure 6 shows the apparatus being used to cap a cylinder with plaster of paris.

The plates on which the cylinders were placed were perfectly horizontal and the cylinders were set vertical as is shown in the

Fig. 2.—Showing two rough plaster of paris bases.

Fig. 3.—Showing the cylinders in the molds. The glass plate used in applying the standard cap to the center cylinder is in place.

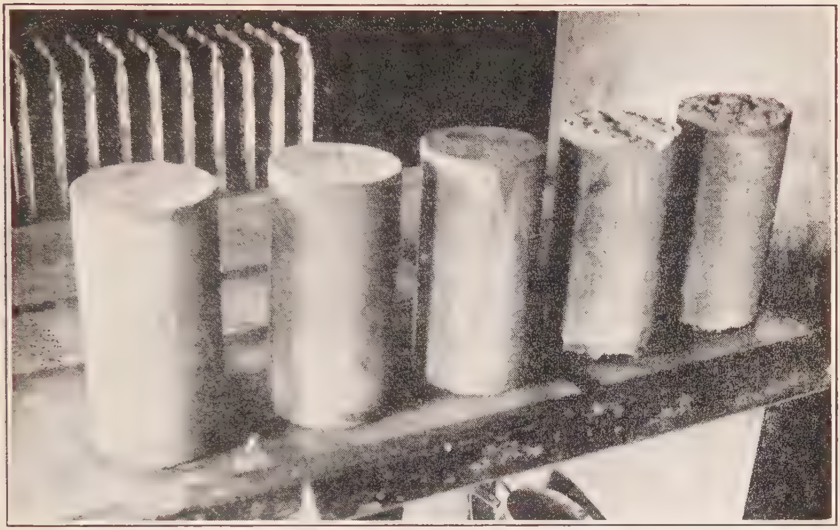

Fig. 4.—Showing the end conditions obtained on the cylinders. The bottom ends of the two outside cylinders have been turned up to show the effect of the bases. A standard cap has been applied to the center cylinder.

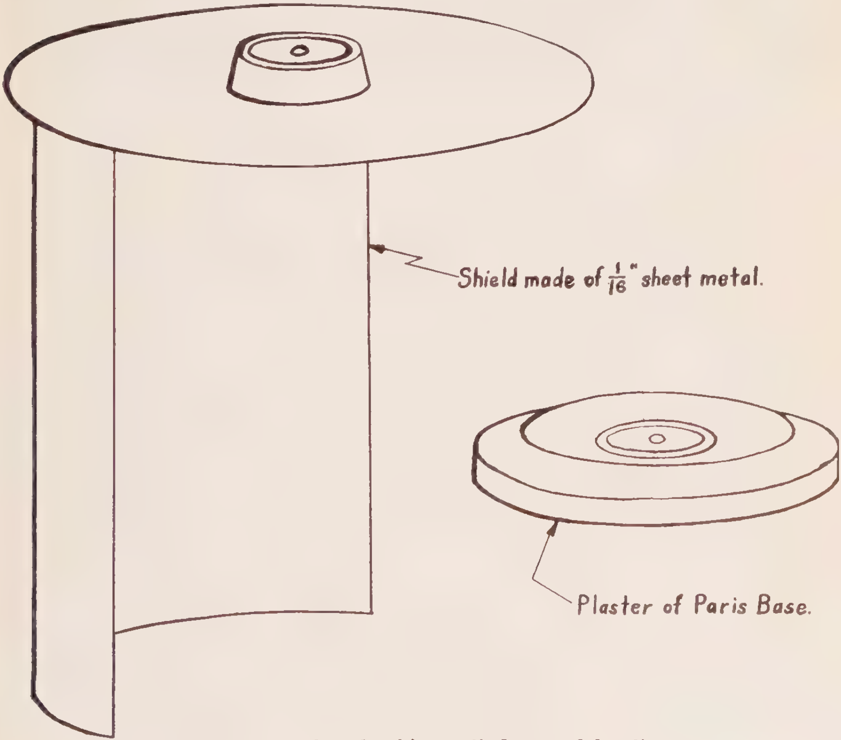

Fig. 5.—Apparatus for plumbing cylinders and leveling caps.

picture on the left. In this way the lower cap ends were made perpendicular to the cylinder sides.

As soon as the lower caps became sufficiently solid the upper caps were applied and made parallel to the bottom caps by leveling the upper glass plates. This equipment has proved itself

Fig. 6.—Left. Setting cylinder vertical on horizontal glass plate while applying lower cap. Right. Leveling upper glass plate while applying cap to the upper end.

very adaptable to our needs in capping field cylinders. The purpose of removing the cylinder with the standard cap from the water was to subject it to the same identical curing conditions as the other cylinders.

The standard cap was applied to the upper end of 1 cylinder in each batch 2 to 4 hours after it was molded and was made of retempered portland cement paste which was mixed at the time the cylinders were made. The upper cap was made smooth by application of a heavy glass plate which was left in place until the following day. A cylinder with the glass plate in place is shown in Figure 2. A cap on the lower end was unnecessary because the cylinder to be capped in this way was molded on a machined steel plate.

The plaster of paris caps were applied to both ends of the cylinders with the capping apparatus. The lower ends were capped by embedding them in plaster of paris paste which had been mixed and placed on the perfectly level glass plates of the capping stand. The upper ends were capped by covering them with

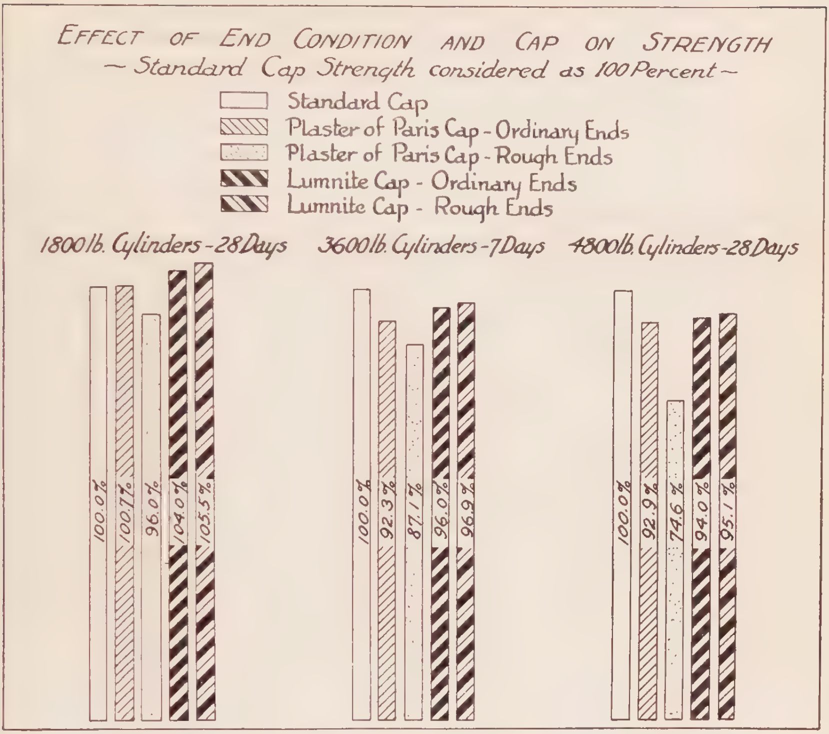

Fig. 7.—Showing the effect of end condition on cap and strength.

plaster of paris paste and smoothing them off with heavy glass plates which were left in place until the paste had thoroly hardened. Two views of capping a cylinder with plaster of paris are shown in Figure 5.

The lumnite caps were applied in the same way as the plaster of paris caps except that a mortar of lumnite cement and fine sand which had been mixed 1 to 3 hours before and retempered just before using was used instead of the plaster of paris paste. The sand used in the mortar passed a 20-mesh sieve.

All of the cylinders were tested on the day following the application of the lumnite and plaster of paris caps with a 150,000-pound testing machine.

RESULTS

In the following tables are given the compressive strengths in pounds per square inch of the test specimens capped in the different ways. The strengths of the cylinders made from each separate batch are placed opposite one another.

TABLE 1.—28-DAY CYLINDERS. (1800 lbs. per sq. in.)

Standard cap	Plaster of paris cap: Ordinary end	Plaster of paris cap: Rough end	Lumnite cap: Ordinary end	Lumnite cap: Rough end
1720	1705	1635	1815	1755
1685	1905	1715	2020	1985
2040	1935	1890	1975	2010
1995	1970	1935	2010	2200
1860	1855	1750	1855	1855
1860(Ave)	1874(Ave)	1785(Ave)	1935(Ave)	1961(Ave)

TABLE 2.—7-DAY CYLINDERS. (3600 lbs. per sq. in.)

Standard cap	Plaster of paris cap: Ordinary end	Plaster of paris cap: Rough end	Lumnite cap: Ordinary end	Lumnite cap: Rough end
3340	3170	2970	3215	3205
3895	3330	3180	3450	3610
3660	3285	3290	3565	3720
3765	3835	3410	3800	3620
4045	3650	3445	3920	3980
3741(Ave)	3454(Ave)	3259(Ave)	3590(Ave)	3627(Ave)

TABLE 3.—28-DAY CYLINDERS. (4800 lbs. per sq. in.)

Standard cap	Plaster of paris cap: Ordinary end	Plaster of paris cap: Rough end	Lumnite cap: Ordinary end	Lumnite cap: Rough end
5225	4570	4220	4765	5140
5130	4800	3560	5190	4835
5410	5085	3510	4750	5190
4920	4550	4010	4875	4575
4215	4125	3265	3825	3940
4980(Ave)	4624(Ave)	3713(Ave)	4681(Ave)	4736(Ave)

Figure 7 shows graphically the averages in the above tables expressed as percentages of the average standard cap strength.

To obtain further proof that the method of capping did effect the strength of field cylinders we tried capping half of each set of the field cylinders of the Colorado State Highway Department with the lumnite cap and the other half with the plaster of paris cap. In most cases a little portland cement was added to the plaster of paris to keep it from setting so fast. Of the 251 sets treated in this way, better than 70 percent tested higher with the lumnite cap. The average strength of the lumnite capped cylinders was 5.69 percent higher than that of the plaster of paris capped cylinders. Most of the sets consisted of only 2 cylinders but some were sets of 4.

In studying Table 1, it will be seen that the maximum variation between strengths of different batches as shown by the standard capped cylinders was about 355 pounds per square inch, or 19.1 percent. From Table 2 the maximum variation in the strength of different batches of 3700-pounds-per-square-inch cylinders was 705 pounds per square inch, or 18.8 percent. Table

3 shows the maximum variation between batches for 4800-pounds-per-square-inch cylinders to be 1295 pounds, or 26.0 percent. It must be remembered that the above figures are based on only 1 cylinder from each batch and that variations caused by the differences in cylinders are included in the variations given. Also nearly all of the batches were made on different days so that the variations due to atmospheric conditions were also included. Nevertheless, it shows that the variation in concrete from day to day even under the closest control is far greater than any error caused by method of capping which is likely to occur.

However, in dealing with field tests of concrete it is the average with which we deal rather than the strength of individual specimens. The sample for any piece of concrete work usually includes 3 or 4 test cylinders from different batches of concrete and the error due to differences in cylinders is compensating, but if we break all of these cylinders after capping them with caps which cause them to give less strength than they should, then all of the set of cylinders are too low and such an error is not compensating but remains the same and the average for that job or that particular set is lower than it should be by the differences caused by the caps. It is seen, therefore, that the method of capping does deserve a great deal of attention, especially when we consider that a plaster of paris cap on a rough-ended cylinder may show only a little better than 70 percent of the true strength. This fact is shown by Figure 7.

Also from Figure 7 it will be seen that various methods of capping do not give the same relative differences in strength when used on cylinders of different strengths. For the 1800-pound cylinders, only the plaster of paris cap on a cylinder with rough ends gave a lower strength than the standard cap method, while for the two higher-strength sets neither the strength of the cylinders with the lumnite cap nor the plaster of paris cap came up to the standard cap. The lumnite cap, judging from the results obtained, always gave a strength higher than the plaster of paris cap.

One of the principal advantages in favor of the lumnite cap is the fact that rough or smooth ends have very little effect on the strength when this cap is used. When the plaster of paris cap is used the end condition has a marked effect on the strength. For all 3 sets of cylinders, the lumnite cap gave a slightly higher strength on a roughened cylinder than on a smooth-ended cylinder. With the plaster of paris cap the reverse was true.

The experiments with field cylinders already referred to also show that capping cylinders with lumnite caps caused them to

give higher strengths than when they were capped with plaster of paris caps. Field cylinders vary considerably in strength, but the average difference of 5.69 percent is probably very close to true difference produced by the use of the 2 caps on cylinders of about 3000 pounds per square inch. This was about the average of the field cylinders tested at that time.

CONCLUSIONS

1. The variation in the strength of individual cylinders is probably greater than any variation likely to occur due to method of capping.

2. Altho the variation due to capping under ordinary conditions is probably negligible when considering individual cylinders, it should be given attention when considering the average of a number of cylinders since the variation due to capping is not compensating.

3. From the results obtained, it appears that the different methods of capping do not give the same relative differences in strength when used on cylinders of various strengths. In other words, the method of capping which gives the highest strength for 1800-pound concrete may not give the highest for 5000-pound concrete.

4. Rough ends appear to have little effect on the strength when the lumnite cap is used.

5. Rough ends give a considerably lower strength when plaster of paris caps are used. The strength shown may be only 70 percent of the true strength in the case of high-strength cylinders.

6. Altho there may be better caps than the lumnite cap, the maximum variation between the strength given by this cap and strength shown by the standard cap is only about 5 percent. Then, too, it appears from the results obtained that strengths shown by these 2 caps are about the same for 3000-pound concrete which is probably very close to the average of all of the cylinders tested. Since the standard cap is the accepted one, it appears that there can be no serious objections to the use of the lumnite cap.

7. An important advantage of the lumnite cap is that it has shown itself to be far easier to apply to uncapped field cylinders than any other cap tried in this laboratory.

8. Apparently it is the strength of the cylinders and not the age which determines the effect which different methods of capping have on the strengths obtained.

Bulletin No. 350 January, 1929

SUGGESTIONS CONCERNING SMALL IRRIGATION PUMPING PLANTS

By W. E. Code

A Vertical Turbine Pump Direct Connected to an Electric Motor.

Colorado Experiment Station
Colorado Agricultural College
Fort Collins

The Colorado Agricultural College

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SUGGESTIONS CONCERNING SMALL IRRIGATION PUMPING PLANTS

BY W. E. CODE, Associate in Irrigation Investigations

Pumping for irrigation is economically feasible in Colorado, and as proper guidance is lacking to the farmer in the development of the water supply for pumping and the selection of the type of equipment best suited to his needs, the following discussion has been prepared to aid him in improving his present installation or in designing a new plant.

Wells

Wells in this state are principally of two classes; those having riveted sheet-metal casing of from 10 to 48 inches in diameter, and those of the pit type from 6 to 15 feet in diameter, using a curb of bricks or concrete blocks.

Riveted casing of galvanized sheet steel in 2- to 3-foot lengths in 12 to 16 gauge, is commonly used. In the smaller sizes, these lengths may be larger at one end than at the other so that they may be slipped together and riveted, or one end of a length may be swedged out to receive the next section. In the larger sizes, the lengths may be butted together and the joint made by riveting the ends to an iron band placed either inside or outside. Perforated sections are made by punching slits about 1½ inches long from the inside without removing any metal and leaving an opening of from 1/64 to ¼ inch wide. Casing may be forced down by loading a long lever arranged across the top of the well, but in the larger sizes, a platform is built on top of the casing and loaded with bags of sand, as shown in Fig. 1.

Figure 1.—Sinking a 48-inch steel well casing near Brush, Colo. About a 16 ton load was used on this casing,—much more than usually needed because of difficulties encountered. *(Photograph by courtesy of Ross Oliver.)*

The smaller sizes of wells are put down by means of a sand bucket, slightly smaller than the casing, except where clay is encoun-

tered and then an auger is used. For shallow depth, these wells may be put down by hand methods, but for the deeper ones using heavy buckets, the standard drilling rig is necessary. When the diameter is 24 inches or over, the orange-peel bucket may be used to remove the material from within the casing. Difficulty may be experienced with an orange-peel bucket when going thru clay which may have to be removed with a spade.

The churning of the sand bucket loosens up the material near the well. One driller takes advantage of this, when the water surface is in clay, by running a large auger hole down on opposite sides of the wall at an angle so that each will intersect its axis near the water surface. While drilling, he feeds into these auger holes small gravel which sinks and follows the casing. This improves the condition for water entry into the well from thin water-bearing strata.

An envelope of gravel may be placed around the well by first sinking a blank casing to the full depth, inserting the final perforated casing and then feeding small uniform gravel into the space between them as the outer one is withdrawn. This gravel screen improves the opportunity for water to enter the casing the full length of the water-bearing area in the well, and prevents the accumulation of fine gravel next to the perforations.

When completed, the well should be developed or worked by the driller. The method usually used is the plunging of the sand bucket up and down, as in the regular drilling operation, in the region of the perforations. This plunging is started usually at the water surface or at the first perforations and applied for short periods of time in 3- or 4-foot stages until the bottom is reached. The movement of the bucket in the areas of perforation will draw considerable sand into the well, that settles to the bottom and can then be removed. This operation should be continued as long as sand enters the well.

In unknown territory, the well driller first puts down a test well to determine the location and extent of the various strata of clay, sand and gravel. In putting down the permanent well, the perforated and the blank casing are assembled so that they will land at the proper depths when the well is completed. It is often desirable to exclude strata of fine sand from the well with blank casing. The size of perforation or slit should be governed by the material found in the test well.

It is very important that a new well be properly pumped for the first time and everything should be in readiness to operate continuously for a day or two. The equipment should be such that the discharge from the pump can be varied, either by valves or by

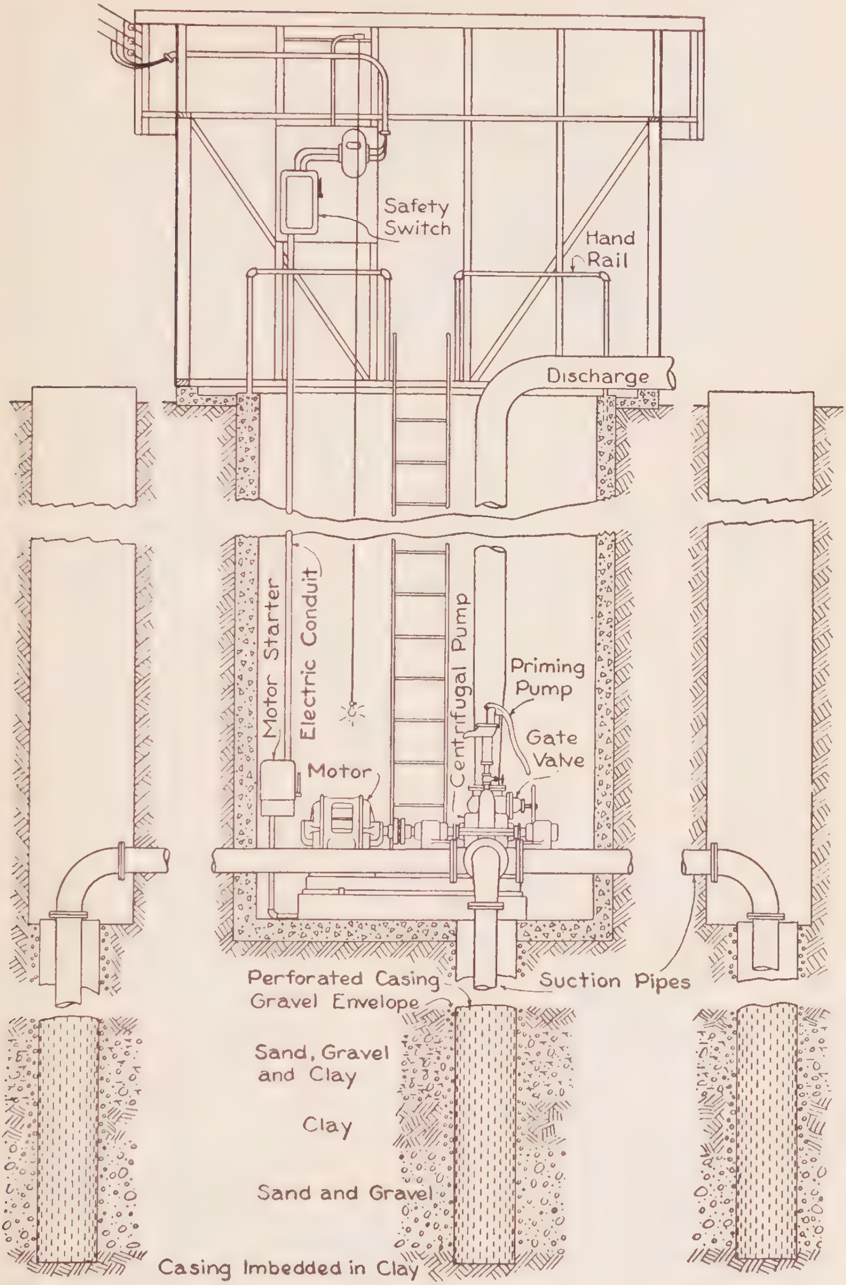

Figure 2.—A horizontal centrifugal pump direct connected to an electric motor in a pit, pumping from three wells simultaneously.

changing the pump speed. At first a small quantity of water should be pumped and the rate maintained until the water becomes clear. The discharge is then increased and usually the water becomes murky again. Pumping is continued until the water becomes clear before the flow is increased. This procedure is carried on until full capacity is reached. New wells operated at full capacity for the first time may become clogged when the pump is stopped, or so much sand may enter the casing as to obstruct the pump, especially if of the turbine type.

The sinking of shallow wells of large size is accomplished usually by hand methods and requires the use of an unwatering pump to keep the water level low enough for men to work. This type of well is dug as an open pit to the water level or to loose sand and gravel where a circular foundation shoe of 2 by 6-inch planks laid flat is built up to a height of 2 or 3 feet. Water enters thru the spaces between the ends of the planks which are staggered in the successive courses. Another type of shoe, offering less resistance to sinking, may be built of beveled 2 by 4-inch lumber set vertically so as to leave narrow spaces between the pieces, and the whole held together by iron bands or horizontal planks cut in arcs of a circle. Bricks or concrete blocks are placed upon the shoe and, as material is removed from underneath, the composite curb sinks by reason of its weight. Considerable caution must be exercised in order to keep the walls plumb. This type of construction is shown in Fig. 4. Large-diameter wells may also be dug by using a reinforced concrete caisson.

It is practically impossible to forecast what the draw-down will be in a well under pumping, especially in an untried district. Wells in a proved area may have similar characteristics and a reasonable estimate may be made of their yield. Since the testing of a well is an added expense, it is frequently considered unnecessary and equipment is purchased wholly unsuited to the conditions that later develop. If the draw-down is excessive, it is usual to sink other auxiliary, adjacent wells which are connected to the main one either by siphoning or by direct connection to the pump.

A practice of obtaining a guarantee from a well driller of a stated quantity of water from a well does not always yield the desired results. Providing the well is deep enough, a wide range of discharges may be obtained, but each will have a different draw-down effect on the well and it may not be economical to lift the water against the head that is required to pump the guaranteed quantity of water. It is safer to contract with an experienced and responsible well driller to complete the well or system of wells that on test proves adequate for the demand imposed upon it.

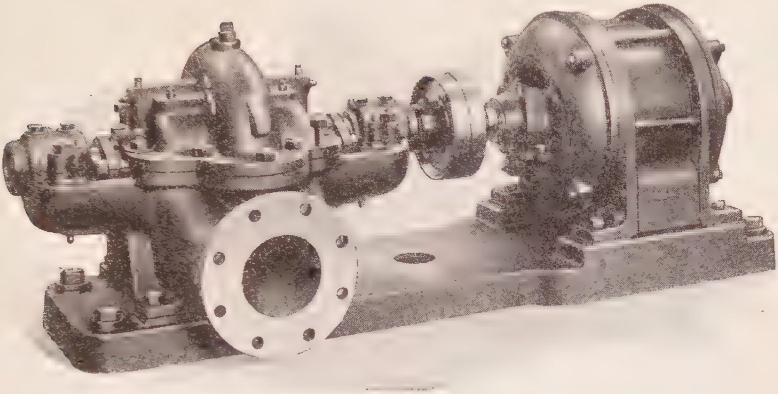

Figure 3. A horizontal centrifugal pump direct connected to an electric motor. This pump has a divided suction and the case is horizontally split allowing easy access to the impeller. *(Electroypc by courtesy of the Allis-Chalmers Mfg. Co.)*

The cost of pit wells varies according to the size and the difficulties encountered in sinking but may be estimated at from $20 to $30 per foot for materials and digging. Estimates for wells with metal casing are given in Table 1.

TABLE 1.—Approximate Cost per Foot of 16-gauge, Galvanized Steel Well Casing and Drilling.

Size Inches	Cost of Casing	Cost of Drilling
6	$ 0.75	$ 1.25
10	1.10	2.00
12	1.20	2.50
15	1.60	3.00
18	1.75	4.00
48	10.00	8.00

When pumping from ditches and lakes, the intakes should be of ample size, substantially built, and deep enough to keep the suction pipe well submerged to prevent the entrance of air. They should be provided with gratings or screens to prevent trash being drawn into the pump.

Pumps

Pumps of various kinds are used thruout the West for irrigation but the most commonly used are the horizontal centrifugal, vertical centrifugal, turbine and propeller pumps. Other types such as the rotary, plunger, bucket, air lift and special forms of the centrifugal are used to a lesser extent under special conditions. The purchaser should consider all the conditions affecting his problem before selecting the equipment. Ordinarily, any one of the first four mentioned types of pump will meet the requirements; however, in the final choice the cost or ease of operation may be the deciding factor. The following brief description of the common

types of pumps is given as a means of assisting in the proper selection of equipment:

Horizontal Centrifugal.—This pump has its axis of rotation horizontal and its rated size is that of the discharge outlet. It is the pump most commonly used, is built in all sizes, and the selling price covers a wide range according to the design and the materials used. Per unit of capacity, it is the cheapest pump obtainable. It may be belt driven and lends itself conveniently to direct electric-motor or auto-engine drive. Since it must be placed above the water level, it is limited by the suction lift which should not exceed 20 feet and preferably 15 feet.

This type occurs in two forms; single or side suction, and double suction, and it should have a convenient, water-sealed packing gland and two bearings. The hydraulic balance of the side-suction pump must be obtained thru some mechanical device that will allow suction pressure to be exerted on both sides of the impeller, while in the double-suction pump this balance is accomplished automatically. Experience shows that the cheap pump lacks mechanical refinements which are necessary for long life and high efficiency. A pitcher pump, attached to the top of the pump case, is the common means of priming and such an arrangement requires a valve in the discharge line, as shown in Fig. 2. If the total lift does not exceed 40 feet, a foot valve at the lower end of the suction pipe may be used and the pump primed by pouring water into the discharge pipe. This method of priming is not always satisfactory because of the uncertain action of this submerged valve. A direct connected, motor driven, horizontal centrifugal pump is shown in Fig. 3.

Vertical Centrifugal.—This type is practically the same as the horizontal centrifugal except that its axis of rotation is vertical. The pump is held in a timber or steel frame which stands vertically in the well and supports the driving shaft to a point above the ground surface where the driving pulley or direct-connected vertical motor is placed. The pump is often placed below the water surface and thus requires no priming; however, the whole frame must be lifted when the packing gland needs attention.

Vibration is a source of trouble in this type of installation and every effort should be made to keep it to a minimum. The frame should be strong, well braced and firmly supported at the top, and the shaft should have bearings at frequent intervals equipped with a convenient lubrication system. Ordinarily a large-sized well is required for its installation but recently a type has been developed that will enter a 24-inch well. Fig. 4 illustrates an installation of this type of pump.

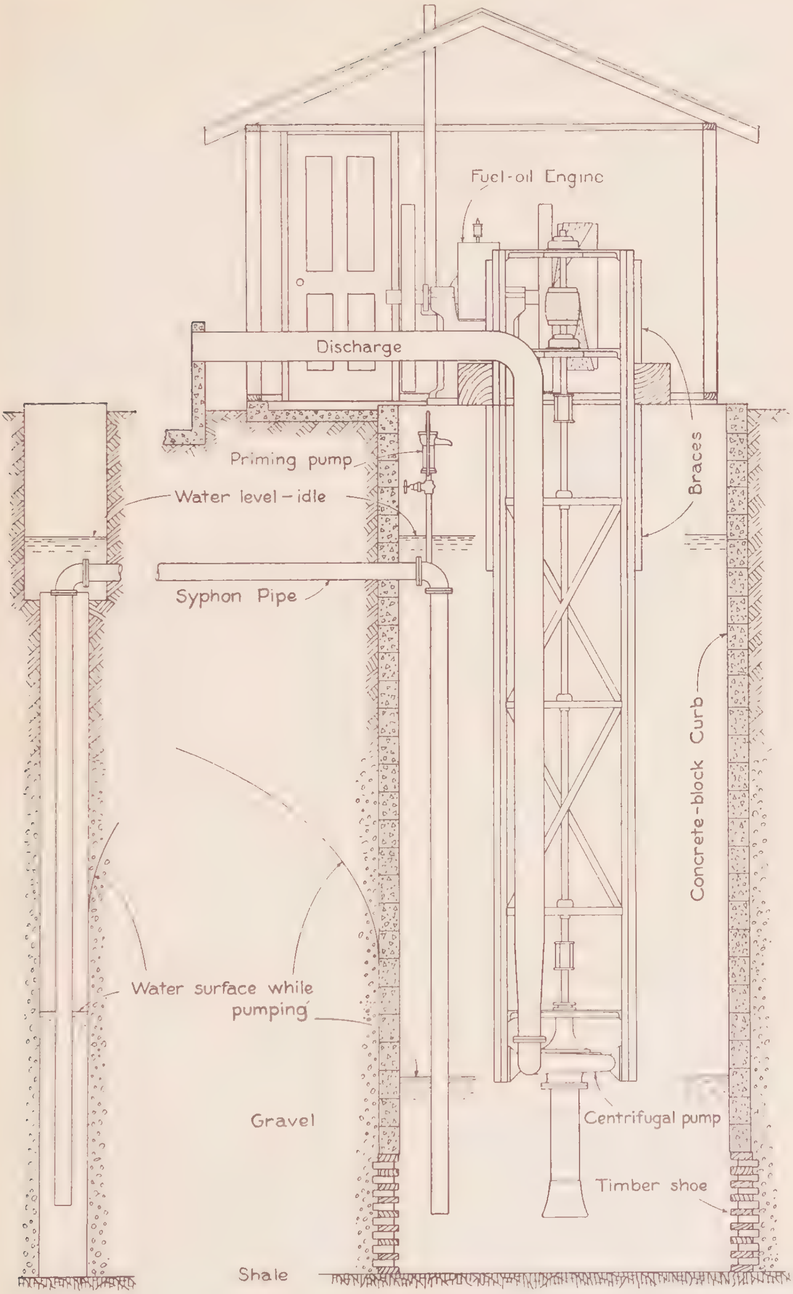

Figure 4.—A vertical centrifugal pump, engine driven, installed in a pit.

The Turbine.—The turbine pump is a development of the vertical centrifugal but instead of the large scroll case for the reception of the water from the impeller, diffusion vanes conduct the water upwards and a pump of small diameter is obtained. Considerable attention has been given to the design of this type of pump to produce a dependable and efficient piece of machinery. It is made in sizes that can be installed in wells of from 6 to 24 inches in diameter. The driving shaft is usually enclosed in a centrally located tube which carries the shaft bearings and the lubrication from the ground surface. The rotating parts and the water in the discharge pipe are carried on a bail or roller bearing in the pump head which is built of cast iron and supports the entire weight of the pump. The depth of setting is limited only by the mechanical difficulties encountered by the increasing weight of the parts when placed deep in a well. This pump is well adapted for lifts of from 40 to 200 feet. It has no draw-down limitations since the pump bowls may be set at any point in the well, or changed later to fit a new condition.

The turbine pump may be obtained with a direct connected motor which is designed as an integral part of the pump head, or with a pulley for belt drive. Its first cost ordinarily is greater than the vertical centrifugal pump and repairs are more costly since the entire pump must be removed from the well with special equipment.

It is not suited to pump from a battery of wells except when the siphon system is used. A derrick over the well is not needed except for the large sizes or when the column pipe is assembled in long lengths. Usually the pump dealer has the equipment necessary to remove the pump from the well for inspection and repairs. Fig. 5 and the cover illustration show installations of the turbine pump.

Propeller Pumps.—In recent years, this type of pump has received a great deal of attention from pump builders and is sometimes classified as a turbine. Essentially it is a long pipe containing the drive shaft along which helical-shaped propellers are placed at definite intervals or grouped at the bottom. The water flows practically upwards at all points and for this reason its hydraulic features are quite different from those of the turbine. For similar conditions this type of pump will deliver more water from a well of small diameter than any other type, with the exception of the air lift.

The principal objection in the past to these pumps was from the mechanical standpoint of maintaining bearings inside the discharge pipe. These bearings are either oil or water lubricated and are now proving to be satisfactory.

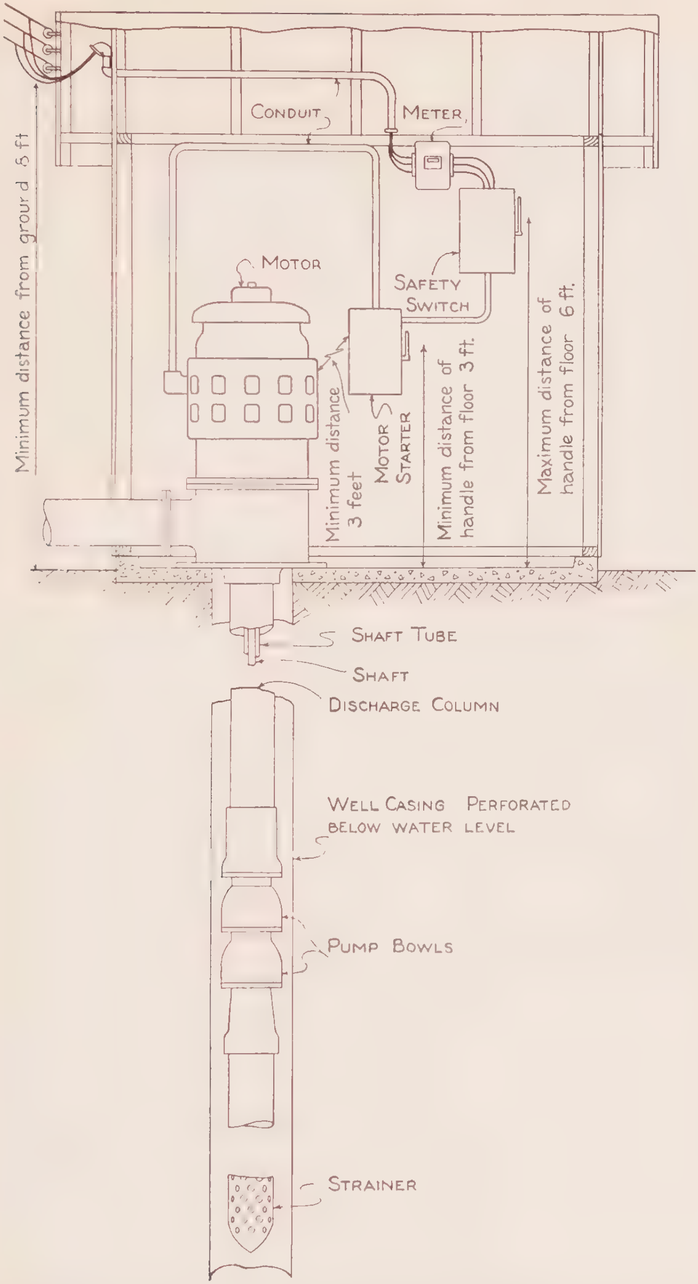

Figure 5.—A vertical turbine pump direct connected to an electric motor. This pump, being self priming, may be arranged for automatic starting after a stop due to a power interruption. Note recommendations for certain clearances.

Favorable conditions for high efficiency in centrifugal and turbine pumps range between capacities of from 400 to 4,000 gallons per minute and heads of from 20 to 80 feet. An efficiency of between 45 and 50 percent may be expected in pumping 200 gallons per minute against a 20-foot head, while 70 to 75 percent may be obtained in pumping 1,500 gallons per minute against a 60-foot head. Under very favorable conditions, efficiencies exceeding 80 percent have been obtained. Propeller pumps may give better efficiencies for small discharges than those mentioned above but, in general, they follow the same ranges.

The vertical centrifugal, turbine and propeller pumps, being self-priming, are well adapted to the automatic feature of electric drive. This feature consists of a special electrical device which allows the motor to start again after a stop, due to a power interruption such as is caused by lightning during a storm.

Other Types.—There are many varieties of centrifugal pumps designed to meet special conditions or of temporary experimental manufacture. Ordinarily, the pump irrigator should select standard machinery and avoid new or untried pumps.

There are many designs of the rotary pump which depend on a rubbing or rolling contact to obtain a positive displacement of the water. As the rotating elements wear in this pump, its initial high efficiency is considerably impaired. In general, this type is not suitable for irrigation pumping.

Bucket pumps find their place in raising water from lakes or ditches where a constant water level at the source is maintained.

The air-lift requires a depth of water in a well not less than twice the distance that the water is to be raised. Air under pressure is forced into the discharge pipe thru a special device at the bottom, which is so designed that the air will be broken up into small bubbles. Large quantities of water may be pumped from a small well by this method and it has a distinct advantage in that there are no moving parts in the well. Its disadvantages are in its relatively low efficiency, seldom greater than 45 percent, the depth of submergence required, and the relatively high first cost.

Plunger pumps are of low capacity and used mainly for high lifts. When double acting with overlapping stroke, their efficiency is very high. In Colorado, the ordinary single-acting pump, driven by a windmill or small engine, is used to irrigate lawns or small gardens.

Under favorable circumstances of obtaining water and head, the hydraulic ram may be employed to furnish water cheaply in small quantities.

Power

Gasoline and oil engines are rated on brake horsepower and to obtain ease and reliability of operation, they should not be fully loaded. For stationary work, the heavy, slow-speed engine should be used because of its long life. In the larger sizes, distillate or fuel oil may be used, which can be purchased for about two-thirds the price of gasoline. Hot-head engines are designed to operate on the lower grade fuels, such as "27 plus," which may not be readily obtained on the local market, as well as kerosene and distillate. The fuel economy of a hot-head or semi-Diesel engine is usually greater than that of an ordinary, electric-ignition engine but is more costly. Generally speaking, the Diesel engine, altho the most efficient, is not suitable as power for small installations because of the high cost and expert attendance required in its operation. Internal combustion engines, unless of ample proportions, will seldom develop their rated horsepower at altitudes that obtain in Colorado. Allowance should be made also for depreciation in efficiency as the cylinders, piston rings and other moving parts become worn. Poor performance and a dropping off in speed, with a consequent diminution in the amount of water pumped, result from not having a surplus of power when the engine is new. The tractor often proves the most economical source of power for pumping when not required for other farm operations. This is especially true if the pumping plant is used but a short time each year.

The full horsepower rating of an electric motor can always be relied upon and often a slight continuous overload. Automatic electrical devices may be installed whereby the motor will start again after a stop due to power interruptions. A motor has a much longer life than the internal combustion engine and its ease and convenience of operation and automatic features make it the ideal source of power.

Plant Design

The smallest practicable plant is the most economical from the standpoint of cost of operation. However, certain conditions of farm management, the method of irrigation and the cost of water distribution may prove such a plant to be too small. All these factors must be considered as a group in order to select a plant which is of the proper size for the convenient and economic operation of the farm as a whole.

Oversized plants cause the following additional cost:

1—Extra first cost of pump and motor or engine;
2—Greater draw-down in the well, or additional wells;
3—Greater "readiness-to-serve" charge on a motor, or more power to be paid for at the maximum rate.

In order to determine the size of the plant, certain assumptions must be made, viz.: The number of hours per day and the number of days per month of maximum use that a plant will be operated. The general method of determining the requirements of pump capacity and power is illustrated in the following problem:

Assume that on an 80-acre farm, one 5-inch irrigation is to be applied during a period of 30 days by pumping for one-third of the time, and that the water is to be lifted against a total head of 30 feet.

The total quantity of water to be pumped will be $5/12 \times 80 = 33.33$ acre-feet, or at the rate of 1.11 acre-feet per 24-hour day. This rate requires a continuous flow of 0.56 cubic-foot per second[1]. Since the plant is to be operated but one-third of the time, then the pump must deliver three times this rate or 1.68 cubic-feet per second (755 gals. per minute)[2]. The power represented by lifting this quantity of water 30 feet is $(1.68 \times 30) \div 8.8 = 5.73$ water horsepower[3]. If the pump is 60 percent efficient, then the necessary power to be applied to the pump is $5.73 \div 0.60 = 9.55$ horsepower. The motor size, either for direct or belt drive, will be 10 horsepower, or a gasoline engine of at least 12 or preferably 15 horsepower.

The kind of well required will be governed by the particular local conditions. In many areas the well is limited in depth to 30 or 35 feet by a thick stratum of sandstone or shale, and the water-yielding material may be but 10 or 15 feet thick. These conditions limit the draw-down and are unfavorable for a large yield. Within reasonable limits under such conditions, the larger the well diameter the greater the yield; however, this point cannot be determined until fully tested. To augment the yield it is usual to drill other small wells at a distance of 30 or 40 feet and connect them to the pump suction pipe, or to siphon them into the main well. Sometimes a battery of small wells is drilled, the number depending on the quantity of water desired and the character of the gravel stratum, all connected to a common suction pipe to the pump. Where a depth of 50 feet or more is obtainable in good water-bearing material, a single drilled well may produce the required amount of water. The yield conditions from any well in water-bearing material improve with the depth, and the size of well becomes of lesser importance.

There is but one set of conditions of speed, head and discharge for the centrifugal, turbine or propeller pumps at which the efficiency is a maximum. A change in any one of these factors affects

[1]One cubic-foot per second flowing for 24 hours equals approximately 2 acre-feet per day.

[2]One cubic-foot per second equals approximately 450 gallons per minute.

[3]Water horsepower $= \dfrac{\text{cubic-feet per second x lift in feet}}{8.8}$

the others; an increase of speed ordinarily causes an increase in discharge or gives the same discharge at a higher head, or if the speed remains constant and the head is increased, less water will be pumped. It is seldom that the conditions are such that a pump will deliver its peak efficiency but it is possible to purchase one that fits reasonably close. The rated size of stock pump may deliver the desired quantity of water but still be poorly suited to the conditions to give reasonable efficiency. Impellers are made in various diameters and with various shapes of vanes for the same pump case in order to meet specific conditions.

The horizontal centrifugal pump must be placed so that the suction lift does not exceed the practicable limit of about 20 feet. It may be set in deep pits when direct connected to an electric motor but the operation becomes inconvenient when the pit is over 40 feet deep. The maximum depth at which this type of pump can be set is about 20 feet when belt driven from the ground surface. The vertical centrifugal pump usually requires a pit at least 5 feet in diameter for its installation and the depth of setting is limited to about 50 feet because of the long shaft and frame. Its use is particularly indicated for a fluctuating water level or where the drawdown in the well is beyond the reach of the horizontal centrifugal pump. The turbine and propeller pumps are adaptable for pumping from greater depths than are possible with the vertical centrifugal, and from wells of small diameter. Conditions for the use of the turbine and the vertical centrifugal overlap for the moderate depths.

As a protection against the entry of silt or sand into the sealing gland of a centrifugal pump, it may be necessary to provide a settling tank so arranged that only clear water will be used thru the gland. This precaution should always be made when the well is first pumped. See Fig. 6.

In the selection of piping, the pump should be set in such a position that unnecessary elbows, tees and other fittings are eliminated. In connecting a small pipe to a larger one, a tapering section of length equal to 2½ times the small pipe diameter should be used, and on turns, an elbow of long radius.

Good material is usually the cheapest. Standard flanged pipe should be used on the suction side of the pump and if pumping from a battery of wells, the size of pipe should be proportioned so that the friction loss will be low and equalized. Usually a long discharge line is made larger than the discharge outlet of the pump to reduce the friction head.

When steel pipe is used on long lines, it should be carried above the ground surface and given an occasional coat of preservative.

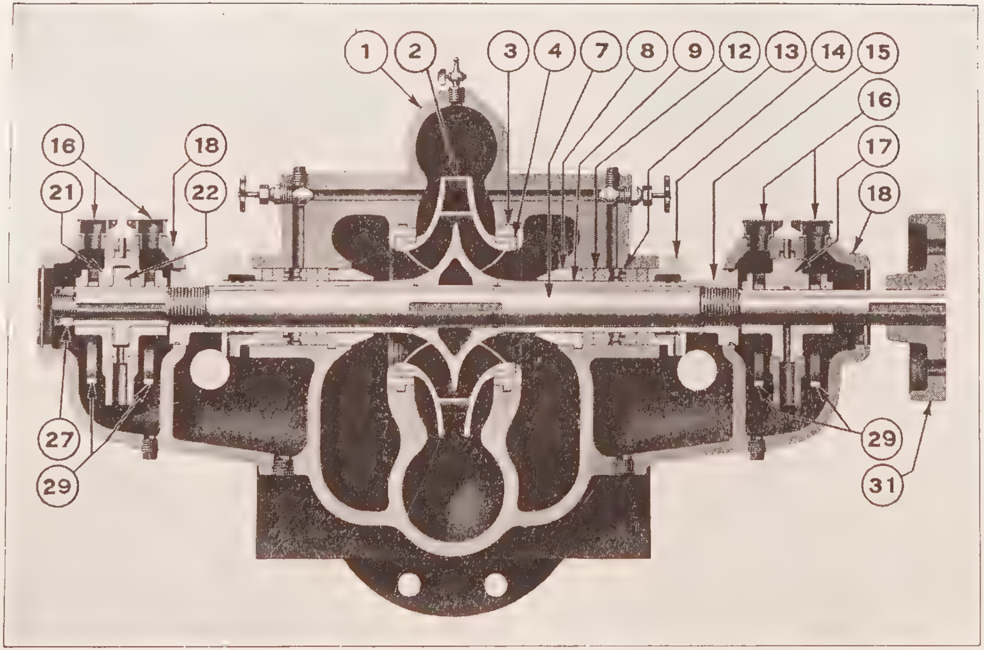

Figure 6.—A vertical section thru a horizontal centrifugal pump showing construction details.
(Electrotype by courtesy of Allis-Chalmers Mfg. Co.)

LEGEND

1—Casing.
2—Enclosed Runner.
3—Casing Wearing Ring.
4—Runner Wearing Ring.
7—Shaft.
8—Stuffing Box Bushing.
9—Shaft Sleeve.
12—Packing.
13—Waterseal Ring.
14—Gland.
15—Shaft Sleeve Nut.
16—Oil Hole Covers.
17—Bearing Shell.
18—Bearing Cap.
21—Thrust Bearing.
22—Thrust Sleeve.
27—Retaining Nut.
29—Oil Ring.
31—Pump Half Coupling.

Such exposed line of riveted 16- or 18-gauge steel should be serviceable for at least 20 years. Pipe lines under pressure have longer life than those operating under suction conditions.

The use of valves in connection with priming deserves careful study. Check valves and foot valves should not be put in long lines. A foot valve should not be used if the total head is greater than 40 feet or the discharge pipe is longer than 50 feet because, being quick acting, a water hammer is set up when the pump stops and rupture of the pump or piping may result. On a low lift, a foot valve alone may suffice for priming when water can be poured into the discharge pipe. For the higher lifts, a gate valve is placed in the discharge pipe just above the pump, and a pitcher or tank pump used to exhaust the air from the system in priming. In a battery-well installation, involving a long suction line, it is often desirable to use a power-driven priming pump. Air leaks in the pump or suction pipe greatly extend the time of, or prevent priming, and decrease the pump efficiency.

Excessive belt tightness and the use of idlers are to be avoided in preventing slippage which is better accomplished by the weight of the belt when the distance between pulleys is correct. Gasoline engines require a greater distance between pulley centers than motors, usually not less than 20 feet. The belt should be of the correct thickness and width, according to the horsepower transmitted and the pulley diameters. A thick belt should not be used on a pulley of small diameter. If a horizontal centrifugal pump is belt driven, the inclination of the belt should not exceed 45 degrees.

Most gasoline engines are designed to pull from the bottom of the pulley and therefore must be set on the proper side of the pump to produce correct rotation. The recommendation of the manufacturer should be followed as to the size of the foundation.

It is usually desirable to have a tank cooling system rather than to use the circulating water direct from the pump, for, if the pump should lose its priming, the engine would soon become overheated and injured. It is often necessary to raise the water above the useful lift in order to force water thru the cooling system of the engine, thereby adding extra cost to the pumping operation.

An electric motor should be carefully leveled in order to prevent end thrust and be securely bolted down to adequate foundations. Should the motor be developing its full power, it is essential that it have ample ventilation, especially during hot weather. It is recommended that the wiring of motors for farm pumping be done by or under the supervision of the power company furnishing the electricity. Outside wires are to be kept at least 8 feet from the

ground. All power wires inside the pump house should be in conduit. Knife switches should be of the enclosed safety type. The starter should be of the size and type recommended by the motor manufacturer and placed not closer than 3 feet from the pump or motor except in the case of the push-button line starter.

In damp places, as in the bottom of pits, it is often advisable to operate the starter while standing on a glass insulated stool. Protection against lightning should be provided on the nearest power pole. Power voltage should be either 220 or 440, preferably the former. The use of 2,200 volt current thru the motor is positively dangerous and should not be considered, regardless of savings in power equipment.

When the plant is completed, a permanent and safe means of conducting the water away from the pump should be built immediately. A concrete box should be built, so designed that the water may be easily diverted in any desired direction. The discharge pipe should not be carried higher than flow conditions in the box necessitate.

Plant Care

A shelter should always be provided for the plant, even if of crude design or cheap material. Protect the machinery; the better its appearance the more likely it will be to receive attention, as rusty or grimy equipment promotes an attitude of laxity in proper care. Keep the shelter house clean and avoid water on the floor by providing drains to the well or out of doors.

The pump packing glands need attention periodically. They should not be drawn up so tight that heating results, as this wastes power and the pressure may sear the shaft. Packing will not stay in a satisfactory condition if the shaft is rough. Ordinarily the nuts can be set tight enough with the fingers or a light wrench. Where hard grease is used in sealing, the grease cup will probably need filling once a day and if water-sealed, the water flow will need daily inspection. Before freezing weather, the horizontal centrifugal pump in an exposed position should be drained, as well as all connected piping. The priming pump should be kept in repair and convenient in its operation.

Belts should not be kept in full tension during long periods of disuse. Motors usually have screws in their base for making belt adjustments and should be loosened to release the tension. The belt must be removed from the pulley of the gasoline engine to accomplish this result. The belt splice must be inspected frequently to see if it is pulling uniformly because unequal strain on the splice will cause the belt to run unevenly and may damage a rubber belt by

ripping. Belts of any sort should not be exposed to the weather and should be properly stored after the pumping season.

Motors require but little attention, the most important thing being to keep the oil at the proper level in the reservoirs, using the best quality of oil designated for that purpose. Dust caps should always be kept closed. If the motor accidentally becomes submerged, attempt should not be made to operate it again without advice from someone thoroly familiar with motors. As an index to plant condition, the operator of an electrically driven plant should learn to compute the demand on the motor by counting the revolutions of the meter disk over a period of time. This will serve as a check on the condition of the pump and its bearings. A record should be kept each season of the number of hours of pumping, number of kilowatts used, and the power bill, for the purpose of comparing operation costs.

Gasoline engines need frequent daily attention for the inspection of all points of lubrication, the temperature of the cooling water, and fuel oil supply. Care must be taken to drain all water in freezing weather and it is always good practice to leave the piston out to the extreme stroke when the engine is not in use, to prevent dust from settling on the cylinder walls.

Clean oils and greases for their respective uses should always be on hand.

Wells should not be covered in such a way that they are inaccessible. It is often desirable to inspect the well and note the water level when idle or while pumping, as a matter of record, because a lowered water table may be a reason for an increase in power demand. It may be desirable to sound the well occasionally to determine the extent of accumulation of sand in the bottom. The well should be protected against the entrance of any surface water, trash, or small animals. Attention is drawn to the fact that small pieces of wood entering a well will become water-logged and sink, and, on being drawn into the suction, may cause trouble by lodging in the pump runner, thus causing a diminished flow and an unbalanced condition. There is also the element of danger in breakage of the impeller or pump case by the lodging of such trash.

Estimates of Cost

The prospective irrigation pumping-plant owner should investigate, as completely as possible, its probable cost. It is not possible in this bulletin to give in detail all the items of the cost of a plant since each will have its own peculiarities of construction and these items necessarily must be obtained from a pump dealer or well driller. When investigating the cost of a motor, it is necessary to know the speed at which it runs as well as the horsepower and

whether it is equipped with a base, pulley or starting device. Transformers are sometimes furnished to large users of current by the power company as well as short pole lines. In cases where the transformers must be purchased, they are usually sold at no profit. Their cost is dependent on the primary voltage as well as the capacity. Pole lines for three-phase service will cost about $1,000 per mile. Engines may or may not be fully equipped with a pulley, clutch, cooling water system, or fuel tank. A centrifugal pump may be for belt drive or on an extended base for motor drive. The cost of a turbine pump varies according to its size, number of bowls and the length of the discharge column. In order to obtain guarantees for satisfactory operation, it is desirable that the major units of a plant be purchased from the same dealer so as to avoid divided responsibility.

No estimate of cost is complete unless the item of depreciation is taken into consideration. There comes a time when all or part of the machinery will be worn out and replacement necessary. Theoretically, a certain sum should be set aside each year so that when the part is worn out, funds are available for its replacement. Usually the extent of use governs the rate of depreciation, and the plant that is used 4 months per year will have about twice the depreciation of one used but 2 months per year. Besides use, the life of machinery is shortened thru lack of proper care, and depreciation also takes place by its becoming obsolete thru age.

Interest on the investment and taxes are the same, whether the plant is used much or little. These are unseen expenses that influence farm profits and must be taken into consideration, especially when the plant is intended to be used for an auxiliary water supply.

The farmer using a pump as a sole source for irrigation water should be especially interested in obtaining a pump of high efficiency. His is a continual expense, and a difference of a small percentage in efficiency is reflected to a greater degree in his power bill. Often a motor of smaller size can be used with the more efficient pump, and besides effecting a saving in purchase cost, he also profits by a lower power rate. There is less reason for investing extra money in a highly efficient, permanent plant which is to be operated but a very short time each season.

Cost estimates are given below of three alternative plants to provide water for the conditions as given in the problem on page 13. It is assumed that 140 acre-feet of water are to be pumped from a 12-inch well, 65 feet deep in which the water level is 18 feet below the ground surface. For each the discharge will be 755 gallons per minute, the lift 30 feet, and the water horsepower 5.73.

PLANT NO. 1. Equipment to consist of a high grade, horizontal centrifugal pump direct connected to an electric motor in a pit 15 feet deep. The motor efficiency is to be 89 percent and pump efficiency 60 percent.

Cost of plant:

Well 50 feet deep below bottom of pit, drilling at $2.50 per foot	$ 125.00
Developing and extra cost because of pit	40.00
Well casing 12-inch, 16-gauge, galvanized, 50 feet at $1.20 per foot	60.00
Concrete pit, 6x8x15 feet, 6-inch walls	165.00
Five-inch pump, 10 horsepower motor, starter, switches, piping and valves, installed	625.00
Transformers	300.00
Shelter and wiring	150.00
Total cost	1465.00

Operating cost:

Interest on $1465 at 6 percent	87.90
Taxes 1 percent	14.65
Depreciation on machinery, $655 at 6 percent	39.30
Depreciation on well and shelter, $510 at 4 percent	20.40
[4]Power consumed, 1000 hours at 8 kilowatts per hour—8000 kilowatt hours	230.00
Repairs, lubricating oil	7.00
Attendance	20.00
Total annual cost	419.25
Cost per acre per year	5.24
Cost per acre-foot	2.99

PLANT NO. 2.—Equipment to consist of same quality horizontal centrifugal pump as in the preceding plant, driven by an engine using distillate for fuel. Pump efficiency to be 60 percent.

Cost of plant:

Well, 50 feet deep, drilling at $2.50 per foot	$ 125.00
Developing and extra cost because of pit	40.00
Well casing 12-inch, 16-gauge, galvanized, 50 feet at $1.20 per foot	60.00
Concrete pit 6x6x15 feet, 6-inch walls	150.00
Five-inch pump, pipe and valves	340.00
Fifteen horsepower engine, accessories and belt	625.00
Shelter and installation	300.00
Total cost	1640.00

Operating cost:

Interest on $1640 at 6 percent	98.40
Taxes, 1 percent	16.40
Depreciation on machinery, $1115 at 9 percent	100.35
Depreciation on well and shelter, $525 at 4 percent	21.00
Distillate consumed, 1⅓ gallons per hour for 1000 hours at 12 cents per gallon	160.00
Repairs and lubricating oil	35.00
Attendance	75.00
Total annual cost	506.15
Cost per acre per year	6.33
Cost per acre-foot	3.62

[4]Cost of power is based on the following rates:
First 200 kilowatt hours per horsepower per season at 5 cents per Kwh.
Next 100 kilowatt hours per horsepower per season at 3 cents per Kwh.
All additional power at 2 cents per Kwh.

PLANT NO. 3.—Equipment to consist of a vertical turbine pump direct conected to an electric motor. The pump head is to be set on the well casing at the ground surface. The motor efficiency is to be 89 percent and the pump efficiency 60 percent.

Cost of plant:

Well, 65 deep, drilling at $2.50 per foot	$ 162.00
Developing	20.00
Well casing, 12-inch, 16-gauge, galvanized, 65 feet at $1.20 per foot	78.00
Pump and motor, installed	800.00
Transformers	300.00
Shelter, switches and wiring	150.00
Total cost	1510.00

Operating cost:

Interest on $1510 at 6 percent	90.60
Taxes, 1 percent	15.10
Depreciation on machinery, $850 at 8 percent	68.00
Depreciation on well and shelter, $360 at 4 percent	14.40
[4]Power consumed, 1000 hours at 8 kilowatts per hour—8000 kilowatt hours	230.00
Repairs and lubricating oil	20.00
Attendance	12.00
Total annual cost	450.10
Cost per acre per year	5.63
Cost per acre-foot	3.22

[4]Cost of power is based on the following rates:
First 200 kilowatt hours per horsepower per season at 5 cents per Kwh.
Next 100 kilowatt hours per horsepower per season at 3 cents per Kwh.
All additional power at ....2 cents per Kwh.

The Irrigation Investigations Section of the Colorado Experiment Station is now making an extensive survey of the

IRRIGATION PUMPING

problem in the state. Those interested in this work should request that their name be put on the mailing list for the publication covering this investigation.

A recent bulletin, "The Improved Venturi Flume," issued by the station will be of interest to those engaged in the measurement of water for irrigation. A copy may be had by addressing the

Colorado Experiment Station

Fort Collins

BULLETIN NO. 351 MAY, 1929

SOME COMMON DISEASES OF ORNAMENTAL PLANTS

BY E. L. LECLERG

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**Deceased.

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SOME COMMON DISEASES OF ORNAMENTAL PLANTS

By E. L. LeClerg

Ornamental plants are subject to a number of diseases, but because of their lesser economic significance they have not received the attention given to the diseases of vegetables and field crops. The experiments that have been made on the diseases of ornamental plants and what is known concerning them is scattered thruout various books and magazines and is not generally available to the grower, especially the home gardener who may often be as much concerned about a disease of his flowers as the commercial grower.

In order to better understand the diseases commonly found on ornamentals, it must be recognized that while a few are caused by bacteria, most of them are caused by fungi or molds. These are microscopic organisms, colorless and thread-like in structure. They cannot make their own food and must live as parasites on green plants such as our flowers and shrubs. Some of these fungi or molds live on the surface of leaves as do the powdery mildews and can readily be killed by spraying; others penetrate into the tissues of the leaf, stem or root of the plant causing rots, blights or wilts. When a plant wilts or dies and there is no visible evidence of the action of an organism on stem or leaves, examination will usually show that the root is rotted. Such diseases of roots are practically impossible to remedy; the plants should be destroyed and a different kind of plant grown in their place. Diseased plants or parts of plants should be burned to prevent spread.

The fungi causing most of the diseases of ornamentals are spread by microscopic cells called spores, which correspond to the seeds of higher plants. These spores are spread from plant to plant by wind or rain or splashing water from the hose and start new infections.

While some generalities as the above can be made regarding plant diseases, specific treatment of each disease is preferable.

It is the purpose of this bulletin to bring together information regarding some of the more common diseases of ornamental plants found in Colorado. The plants attacked are arranged alphabetically and the diseases listed and discussed under these

headings. An attempt is made to make available brief descriptions of the diseases together with such methods as are known to aid in their control.

ASTER, *Callistephus chinensis*

YELLOWS.—The cause of aster yellows is unknown. No organism has been found in any part of the plant to account for the disease. The affected parts of diseased plants do not die or wilt in the early stages of the disease, but exhibit only a "spindling" yellow growth. (Fig. 1.) "Yellows" begins to appear after

Fig. 1. "Yellows" disease of aster. A, diseased plant showing wilted condition of leaves and flowers which accompany the yellowing. B, healthy plant.

the plants have become well established in the permanent bed. A light, greenish-yellow color instead of the normal dark green appears at the growing tip of diseased plants. Leaves previously formed do not change their color, but from the point where the trouble begins the succeeding stem and leaves are affected. At the same time, similar yellow shoots begin to appear from the axils of the leaves on the main stem. Nothing has been found in any part of the plant to account for the disease and no remedy

can be recommended for its control. It is known that certain weeds are susceptible to yellows and that the disease can be transmitted from weeds to asters by some insects. All weeds, therefore, should be kept cut in the vicinity of aster plantings.

WILT OR STEM ROT.—Wilt or stem rot is caused by a fungus *(Fusarium conglutinans callistephi)* and is the most common and destructive disease of asters. It first appears soon after the plants are set out in the bed and is generally prevalent from that time on thruout the season. This disease is most noticeable at two periods of the plant's growth, namely, at the time of setting of the plants and the time of blossoming. To the casual observer the presence of this disease is first indicated by the death of the affected plants. A close examination of dead plants will show that the stem of the plant just at the surface of the ground is badly rotted and only the hard inner portion remains. This is the final stage of the disease; however, it may be recognized much earlier.

In the earlier stages of the disease the roots and stem appear perfectly sound and healthy and no indication of injury can be seen except in the wilted, dying lower leaves. Frequently on one side of the plant, one finds a dark discoloration in the outer edge of the harder, woody portion of the stem, where it joins the soft "bark" or cortex which covers it. The affected side of the plant is dull green, wilted or blighted in appearance. A reddish-brown streak is often noticeable up the stem of affected plants.

This disease can be avoided by starting with healthy plants, grown out-of-doors or in cold frames, rather than in greenhouses where the conditions are more favorable to the disease. Seed should be planted in good soil out-of-doors as early as the ground can be thoroly worked and in a place where asters have never been grown before. The young plants should be transplanted to the permanent bed as soon as they are large enough and when conditions are favorable. They should be planted in a cool soil, since the fungus causing this disease grows best in hot, dry soils.

CARNATION, *Dianthus caryophyllus*

STEM ROT.—Stem rot is caused by a fungus *(Fusarium sp.)* and may attack seedlings, cuttings or mature plants. The disease is characterized on seedlings by lesions which appear as small brown spots on the stem at the surface of the soil. These spots increase in size and eventually almost girdle the stem, thus resulting in the collapse of the plant.

Cuttings may be attacked several days after they have been placed in the sand. Similarly the cutting is attacked on the stem just above, or frequently just below, the surface of the sand. The leaves of affected cuttings wilt and the plants fall over. A soft, wet, progressive rot then usually develops at the collar and extends to the surface of the sand.

The symptoms of the disease on a mature plant show the gradual loss of green color and the foliage becomes pale. Wilting results in time, depending upon the condition of the weather. An examination of the stem at the surface of the soil reveals at this time a slimy, wet condition under the bark, which gives this disease its characteristic name "rot." A slight twist is sufficient to slough off the bark and expose the harder tissues underneath. Plants at this stage of the disease are injured beyond recovery.

Steam sterilization is the only effective measure that will eradicate this fungus from the soil. Dry steam forced thru soil at 40 pounds pressure for an hour will destroy the fungus. (See Colo. Sta. Bul. 321.)

Fig. 2. Leaves of carnation plant showing pustules of rust.

RUST.—Rust is a common disease and is especially serious on greenhouse carnations. This disease is caused by a rust fungus *(Uryomyces caryophyllinus)* and appears as elevated ridges about one-eighth to one-fourth of an inch long on the surface of the leaves (Fig. 2). These blisters eventually break and a reddish-brown, powdery mass of spores escapes, which spread the disease from one plant to another.

Watering aerial parts of the plants spreads the disease from leaf to leaf, and

therefore, surface watering should be practiced. Cuttings should only be made from healthy plants. The Enchantress, Mrs. C. W. Ward, White Perfection, Beacon, Matchless, White Wonder, Pink Delight and Benorah are said to be more resistant than others.

CHRYSANTHEMUM, *Chrysanthemum sp.*

LEAF SPOT.—This is a common disease of greenhouse chrysanthemums and is caused by a fungus. Leaf spot does not result in serious losses to growers. The disease is characterized by circular spots on the leaves. (Fig. 3). These spots first have a

Fig. 3. Leaf spot of chrysanthemum. The affected tissue has dropped out in the areas indicated by arrows.

water-soaked appearance, later becoming brown. The lower leaves of the plants are usually attacked first and the disease spreads upward from leaf to leaf. In severe cases where spots become numerous, the leaves may turn yellow and drop.

The application of a 4-4-50 Bordeaux mixture (see Fungicides) will check the spread of the disease if it becomes serious. If only a few of the leaves show spots, they should be picked off and burned. This will tend to check a spread of the disease.

The organism causing leaf spot is spread from plant to plant by sprinkling the foliage. Therefore, surface irrigation should be practiced.

RUST.—This disease is caused by a rust fungus *(Puccinia chrysanthemi)* similar to that causing rust on grains. Like other rusts it forms small blisters which appear on the under surface of the leaf and to some extent on the upper surface. When these blisters mature they break open and expose a dark brown powder, which is a mass of spores. These spores are scattered by the wind and water while sprinkling the foliage. They are responsible for the spread of the disease from plant to plant. In the case of a heavy rust attack, most of the foliage may become affected and the leaves become shriveled and fall from the plant.

If only a few plants are affected, the removal and burning of the diseased leaves as they appear, will tend to stop the spread of this disease. No fungicide will stop this disease without hand picking, but if rightly used, spraying will prove a material assistance. Potassium sulfide (1 ounce to 2 gallons of water) applied at weekly intervals is beneficial.

YELLOWS.—The cause of "yellows" is unknown and shows a great similarity to aster yellows. Due to the obscure nature of the disease it can only be recognized with certainty at flowering time. Diseased plants always produce flowers that are sickly green in color. This green color may not show in the entire flower, but half may be green and the other half of the blossom the normal color of the variety.

Plants grown out-of-doors which show any symptoms of "yellows" should be destroyed, since cuttings from these plants will be affected with this disease. "Yellows" is transmitted by insects in greenhouses. By controlling the insects the disease can be kept in check.

CLEMATIS, *Clematis sp.*

LEAF SPOT may be caused by one of several fungi. This disease is common on clematis. It does not cause serious damage, but only results in the loss of a few lower leaves from the badly infected plants. Leaf spot is limited to the foliage where discolored lesions are produced, similar to the leaf spots found on other ornamental plants.

Spraying with Bordeaux mixture will control leaf spot. Since this fungicide discolors the foliage, picking affected leaves is recommended where the disease is not serious.

COLUMBINE, *Aquilegia sp.*

POWDERY MILDEW is a very common disease on columbines wherever they are grown. It is caused by a fungus *(Erysiphe polygoni)* and as a rule causes very little damage. This disease, like other powdery mildews, forms grayish-white, powdery growths on the leaves. Often the disease becomes so abundant that entire leaves become covered. The fungus is generally most prevalent on the upper surface of the foliage. Due to the winds and the spattering of water, the disease spreads rapidly from leaf to leaf and in severe attacks the lower leaves fall prematurely.

Powdery mildew of columbine can be controlled by spraying with potassium sulfide or dusting with flowers of sulfur. The sulfur should be applied when the leaves are covered with dew.

GERANIUM, *Pelargonium sp.*

BLOSSOM BLIGHT AND LEAF SPOT.—This is the most common disease of geraniums and may cause serious losses in greenhouse stock. It is caused by a fungus *(Botrytis cinerea)*. The disease causes the blossoms to dry up, a week or 10 days sooner than normal. In the early stages of the disease the petals begin to turn black on the edges; then they wilt and begin to drop. The infected petals very often cause infection on the foliage as they fall from the blossoms. Spots of varying sizes are formed on the leaves. These spots are brown and cause the plant to become weakened. If conditions are favorable, these spots increase in size and often infect the entire leaf. The disease is most prevalent on weakened plants and spreads quite rapidly in greenhouses, once infection takes place. Double varieties are most susceptible to the disease.

Sanitation and proper ventilation should be practiced. Diseased plants should be discarded as soon as observed.

GLADIOLUS, *Gladiolus sp.*

HARD ROT is caused by a fungus *(Septoria gladioli)*. The disease becomes most apparent about the last of July or early in August. On the leaves it appears as minute brown or purplish-brown, more or less circular spots. These diseased spots later turn to a reddish-brown or almost black color.

The disease appears on the corms as small water-soaked spots. These spots are reddish brown to brownish black in color. They usually are limited to the sides and the lower half of the corm. These lesions can be more readily seen if the husks are

removed. In the early stages of the disease the lesions are limited to the surface and even in the very late stages do not enter more than one-quarter of an inch into the corm.

Hard rot overwinters on the dead tops of the plants, so all debris in infected fields should be raked up in the fall and burned. Care should be taken to use only disease-free corms. Crop rotation should be practiced. No successful treatment of the corms with chemicals has as yet been found.

PENICILLIUM ROT.—This is typically a storage disease and is caused by a fungus *(Penicillium gladioli)*. This rot is present in many of the gladiolus storage cellars of Colorado. Diseased corms are somewhat softened and show reddish-brown, sunken spots. These spots are often roughened by wrinkles which are in concentric rings. Infection takes place most readily thru

Fig. 4. Bacterial scab of gladioli on the corms.

wounds on the corm. Rot progresses most rapidly at temperatures between 53° and 73° F., and the corm is gradually destroyed. The fungus often grows on the exterior of the corm and forms a bluish covering over the surface.

No fungicides have been found that will control this disease. The most satisfactory method of control is to discard all diseased corms at time of storage. This will tend to check the spread in storage. Care should be exercised in digging and handling not to bruise the corms, since the fungus enters thru such wounds.

SCAB.—This disease is caused by a bacterium *(Bacterium marginatum)* and is widely spread where gladioli are grown. Scab may appear on any part of the leaf. The disease is first recognized by small raised, reddish-brown spots which come together forming large diseased areas. The stem tissue is soon destroyed and the leaves begin to turn yellow and gradually die. Infection is limited to the lower 6 to 8 inches of the leaves, the upper parts having but few spots.

The corms are often affected and show lesions on both the husk and the exterior. The lesions first appear as yellow to light-brown areas which later become almost black (Fig.4). The spots or lesions are mostly round, but may appear as oval or elongated streaks. These lesions become sunken, but do not extend very far into the corm.

Experiments on control have been too meager to indicate the most advisable methods for prevention of scab. Work from other states seems to indicate that some of the commercial organic mercury disinfectants are giving good control. Crop rotation, however, should be practiced, since the organism is thought to live over winter in the soil. Only disease-free corms should be planted.

HOLLYHOCK, *Althae rosea*

RUST.—Rust is the most common disease of hollyhocks and is caused by a fungus *(Puccinia malvacearum)*. This disease is characterized by brownish, erumpent spots on the leaves. These spots are either circular or elongated as shown in Fig. 5. The pustules break open at maturity and a brownish mass of spores escapes. Wind and water spread these spores from plant to plant causing new infection. Only in severe cases do the plants wither and die.

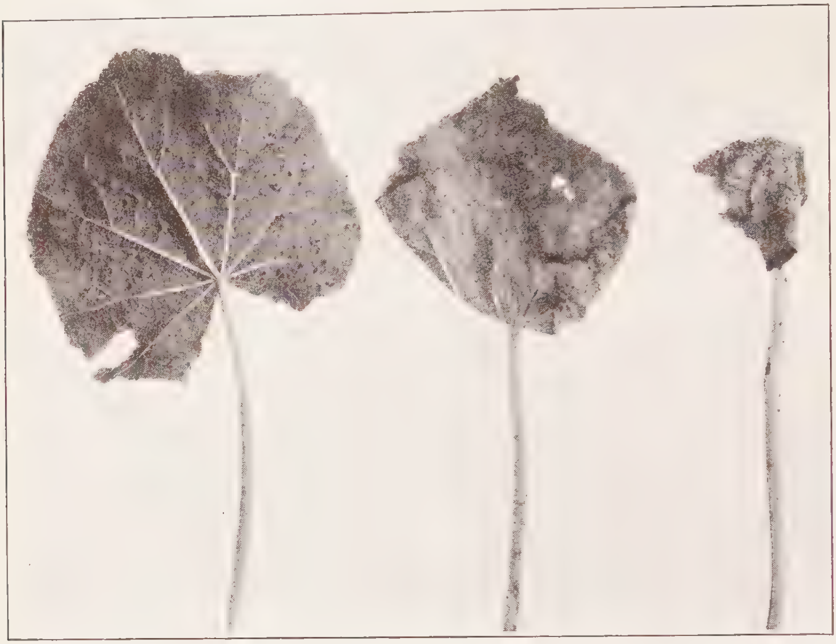

Fig. 5. Diseased hollyhock leaves showing the brown, erumpent pustules of rust and the final dried condition of the leaves.

In the spring care should be practiced to pick off and burn all diseased leaves as soon as they appear. It is best to destroy old plants that are severely attacked by rust and start with new stock. All the diseased plants should be burned in the fall. Rust can be checked by spraying with Bordeaux mixture, but since this spray discolors the foliage it is not frequently used. The effective use of sulfur in controlling rusts on other plants suggests its use on hollyhocks.

HYACINTHUS, *Hyacinthus orientalis*

ROOT ROT is caused by a fungus *(Fusarium sp.)*. See root rot of Narcissus, page 16.

IRIS, *Iris sp.*

LEAF SPOT.—Leaf spot is caused by a fungus *(Didymellina iridis)* and is confined only to the leaves. The first sign of the disease is small brown spots surrounded by a water-soaked margin. The spots turn yellow later in the season. They are more abundant on the tips and spread downward. The terminal portions of the leaves often become brown and die (Fig. 6).

Fig. 6. Leaf spot of iris.

The spots may appear on either surface of the leaves. The diseased areas vary in size from one-quarter to one-half inch in diameter. Sometimes these spots become so numerous that the entire leaf is killed early in the summer.

No fungicide has been found that will control leaf spot. The removal of dead infected leaves in the fall is recommended to stop early spring infection.

SOFT ROT.—This disease is caused by a bacterium *(Bacillus carotovorus)*. The first outward appearance of the disease is a complete yellowing of the leaves and finally the death of the plant. Examination at the base of the plant will show it to be jelly-like and soft. The small rootlets become decayed and often the bulb disintegrates, due to the action of the bacteria.

No treatment is known that will prevent soft rot. Excessive moisture favors the disease. The organism producing soft rot is known to live on several vegetable crops such as carrots, celery, turnips, etc. Bulbs should not be planted on soil known to be infected with this organism.

LARKSPUR, *Delphinium sp.*

POWDERY MILDEW.—This is the most common disease on cultivated larkspurs and is caused by a fungus *(Erysiphe polygoni)*. The leaves become covered with a white, powdery network of fungus filaments. The disease is seldom serious, but may cause the plants to become a paler green. In severe cases the foliage turns yellow and gradually dies.

Mildew can be controlled by the use of potassium sulfide or dusting with flowers of sulfur.

NARCISSUS, *Narcissus sp.*

ROOT ROT is very common on narcissus in this state and is caused by a soil-borne fungus *(Fusarium sp.)*. The disease causes a marked dwarfing of the plants and usually the blossoms do not develop properly. Diseased plants have only a small number of live roots, the remainder being rotted. The basal plate of the bulb is generally decayed. In severe attacks the entire bulb may become decayed.

Bulbs should be sterilized with bichloride of mercury (1:1,000) for one hour before planting. Crop rotation should be practiced, since the fungus lives over in the soil.

PEONY, *Paeonia sp.*

PEONY BLIGHT is caused by a fungus *(Botrytis paeoniae)*. It is quite prevalent and often causes much damage. Plants are affected early in the spring and nearly all parts are attacked. On the stems and leaves it is characterized by large irregular spots, which cause a gradual dying of the leaves. Stems are often rotted near the ground and become girdled. Sometimes the young buds become blasted before they reach maturity, which causes them to blacken and die.

Blight is very difficult to control. All old diseased plants should be removed and burned in the fall. No dusts or sprays have been found effective in controlling this disease.

LEAF SPOT.—This is a common disease of peonia, and is caused by a fungus. It seldom causes very serious losses. The disease appears as chestnut-brown spots and may cover the larger part of the leaves (Fig. 7). On these spots the spores are borne which spread the disease from plant to plant.

Fig. 7. Leaf spot of peonies.

Leaf spot can be controlled by spraying with Bordeaux mixture. Since this spray discolors the leaves, it is preferable to pick affected leaves instead of spraying when the attack is not serious and only a few plants are affected.

PHLOX, *Phlox sp.*

POWDERY MILDEW.—This is a common and often destructive disease of cultivated phlox. It is caused by a fungus *(Erysiphe cichoracearum)*. The leaves and stems become thickly covered with a dirty white powdery growth. The disease starts on the lower leaves and gradually spreads to the upper parts of the plants. In severe attacks the lower leaves fall prematurely and the flowers become dwarfed.

Powdery mildew of phlox can be controlled by spraying with potassium sulfide or dusting with flowers of sulfur.

ROSE, *Rosa sp.*

BLACK SPOT is caused by a fungus *(Diplocarpon rosae)*. The disease appears at any time during the growing season. Usually it does not become destructive until summer, and frequently continues damage during the autumn months. Plants which are attacked drop their leaves early in the season. The leaf buds which normally remain dormant until the next year, open late in the season. This premature defoliation causes the plants to become weakened. As a result of this weakened condition the plants blossom poorly or even not at all in the following year.

Fig. 8. Black spot of rose, showing the smoky black patches of the fungus on the leaves.

Spots are produced on the upper surfaces of the leaves which often attain a diameter of half an inch or more (Fig. 8). These spots are more or less circular in outline with very irregularly fringed borders. They are black in color and frequently coalesce, covering the whole leaves.

Fig. 9. Powdery mildew of rose. A, healthy plant; B, diseased plant, showing the shriveled condition of the mildewed leaves and the white patches of mildew on the stem and thorns as indicated by the arrows.

If only a few plants are grown the disease may be checked by gathering and burning all affected leaves. This should be done either late in the fall or early in the spring before the buds open. Spraying is beneficial in controlling black spot. Ammo-

niacal copper carbonate used once each week is recommended. Lime sulfur or Bordeaux mixtures may be used, but these fungicides leave a coating on the foliage which is sometimes objectionable.

POWDERY MILDEW.—Powdery mildew is caused by a fungus *(Sphaerotheca pannosa)* and is one of the most common and injurious diseases of roses. It is first noticeable as dusty, whitish spots on the young leaves or shoots where the mold grows over the surface, sending down numerous minute, thread-like branches into the leaf cells (Fig. 9). These draw nourishment from the leaves and eventually kill them. These spots enlarge and have a white, powdery appearance. The disease is often present on the stems and thorns, where it appears as a felt-like coating. The mold on the surface of the leaf is covered with enormous numbers of white spores that are readily blown or spattered to other parts of the plant and thus spread infection. As the disease advances, the white mildew appearance is lost and the injured portions become dark in color. The leaves, later in the fall, become covered with small, black, bead-like bodies filled with a second kind of spores, the winter spores. The disease lives over the winter in this stage.

Dusting with flowers of sulfur every 10 days is effective either in the greenhouse or out-of-doors. Spraying with ammoniacal copper carbonate will also control the mildew, but is not as easily used as sulfur dust. Sulfur dust placed on the steam pipes of the greenhouse is an effective method of using sulfur. Potassium sulfide used as a spray will also control powdery mildew.

CROWN GALL.—This is a common disease on greenhouse roses. It is caused by a bacterium *(Bacterium tumefaciens)* and attacks other plants, including apple, pear and peach. Crown gall may be spread by pruning shears or at time of cutting and making of grafts.

The disease is characterized by galls which are formed any place on the stem (Fig. 10) and sometimes on the roots. Crown gall progresses very slowly, beginning as small swellings and increasing in size until eventually the plant becomes stunted and finally dies. The organism causing this disease gains entrance into the plant thru wounds and lives from year to year in the diseased tissue. The crown-gall organism is known to live over winter in the soil.

Fig. 10. Crown gall of rose.

Care should be practiced to use only disease-free stock, especially if the plants are grafted. The point of the union and scion is a very common place of infection in grafted stock. All grafts, therefore, should be wrapped and dipped in Bordeaux paste, which will prevent the entrance of the organism, until the union of scion and stock has calloused.

Infected plants cannot be cured, but should be removed and burned. Since the organism lives over in the soil for several years, roses should not be planted on infected soil. Soil infected with the crown-gall organism can be steam sterilized in greenhouses (See Colo. Sta. Bul. 321).

Pruning shears and grafting knives should be sterilized after being used on affected plants and before using on healthy material. Sterilization can be effected by dipping them in a solution of formaldehyde (1 ounce to 2 gallons of water).

BUD BLIGHT.—This disease is caused by a fungus *(Botrytis cinerea)* and is one of the less common diseases of roses. It is limited in its attack to the undeveloped buds and is characterized by the dropping of the buds and their failure to open. The fungus forms a cobwebby mass in the interior of affected flower buds. A smooth, sunken, dark-colored area is often produced on the stem below the bud and at which point the head falls over.

Sprays are not beneficial in controlling bud blight. All diseased flowers should be picked and burned as soon as noticed so as to check the spread of the disease.

ROSE RUST is caused by a fungus *(Puccinia speciosum)*. The disease is readily recognized in the spring by the bright yellow spots formed on the leaves and stems. This fungus passes thru various stages of growth that are similar to black stem rust of wheat. The yellow spots soon develop into red blisters or streaks in the late summer or early autumn. These red blisters contain many reddish-brown spores in a powdery mass (Fig. 11). They eventually break and the spores spread the disease from plant to plant. In the fall these blisters become black and contain the resting spores of the fungus, in which stage it passes the winter.

Fig. 11. Rose rust pustule on stem as indicated by arrow.

No fungicide has been found that will control this disease. Since the fungus overwinters on old leaves and stems, all diseased plants should be cut and burned in the fall.

SNAPDRAGON, *Antirrhinum majus*

RUST.—Snapdragon rust is caused by a fungus *(Puccinia antirrhini)*. It becomes extremely serious in greenhouses and also is an important disease in the field and garden. The disease is characterized by brownish blisters on the leaves and stem (Fig. 12). These blisters break and the brownish spores escape and are then spread by wind and the spattering of rains. Rust causes the most damage to the lower leaves because of the presence of excessive moisture and under favorable conditions it spreads rapidly. It finally causes the death of the plant.


Fig. 12. Snapdragon rust.

The use of healthy cuttings is advisable. Watering should be done from below, so as to keep the foliage dry. This will help materially to check the spread of the rust fungus. If the disease is not serious, the affected leaves should be picked off. Spraying with potassium sulfide will control the disease in the field.

Snapdragon rust can be controlled in greenhouses by dusting with sulfur. After dusting, the temperature of the house should be kept at 70° F. for three days and with a night temperature of about 60° F. Finely powdered sulfur (sulfur that will pass thru a 200-mesh sieve) should be applied to the plants with a bellows. If the disease is serious and new foliage becomes affected, sulfur should be applied again. Under conditions of light attacks of this rust, dusting every two weeks will control it effectively.

SNOWBERRY, *Symphoricarpos sp.*

Anthracnose.—This disease is very common and is caused by a fungus *(sphaceloma symphoricarpi)*. The disease has only re-

cently received the attention of investigators. Anthracnose is manifest on both the leaves and the berries.

Small, round, dark purple to black spots are produced on the leaves. The centers of these spots soon become lighter in color, changing to a dark gray. The spots slowly increase in size and eventually come together, forming large diseased areas. Very small lesions are often produced on the flower buds.

Fig. 13. Anthracnose of snowberry on the fruit.

Anthracnose appears on the berries as small, round, pinkish lesions (Fig. 13). These lesions or spots are slightly sunken and vary considerably in size. The diseased areas are very often attacked by another fungus *(Altenaria sp.)* which causes soft, watery lesions on the fruit. These water-soaked areas increase rapidly until the entire fruit has been affected. The diseased berries soon dry up and form hard, brown mummies.

No conclusive work is available on the control of anthracnose. The disease undoubtedly overwinters on dead leaves and in the mummies, so that all rubbish about the plants should be raked and burned in the fall.

SUNFLOWER, *Helianthus annuus.*

RUST.—This is a very common disease of sunflowers and is caused by a fungus *(Puccinia helianthi-mollis)*. Rust is manifest on the leaves as small, yellowish or brownish pustules or blisters which later become black. These blisters contain the spores that spread the disease from plant to plant. The pustules frequently become so abundant on the foliage as to render the under surface quite brown. No fungicides have been found to control this rust, altho experience with sulfur on other rusts suggests its use on sunflower rust. Raking and burning all diseased plants in the fall is the most advisable recommendation.

POWDERY MILDEW is caused by a fungus *(Erysiphe cichoracearum)* and is very common on cultivated sunflowers in Colorado. It is conspicuous on the upper surface of the leaves as white patches. Often the disease spreads so as to cover the greater part of the leaf. Later in the summer the leaves become covered with small black bodies, in which stage the disease overwinters.

Powdery mildew can be controlled by spraying with potassium sulfide or dusting with flowers of sulphur.

SWEET PEAS, *Lathyrus odoratus*

MILDEW.—Like other mildews, this disease is caused by a fungus *(Erysiphe polygoni)*. Mildew is a very common disease of sweet peas grown out-of-doors and in greenhouses. It starts as a white, powdery growth on the lower leaves. The leaves turn yellow and gradually die.

Mildew can be controlled out-of-doors by the use of potassium sulfide and in the greenhouse by dusting with flowers of sulfur.

TULIP, *Tulipa sp.*

BLIGHT.—Tulip blight *(Botrytis Tulipæ)* is a fungus disease which manifests itself on the flowers, bulbs, leaves and stalks. The first outward appearance of the disease on the blossoms is as small, white to light-brown spots on the petals. These spots enlarge until the petals become dry and wrinkled. This gives a blighted appearance to the entire flower. The flower is sometimes prevented from opening by infection taking place in the bud.

The disease appears on affected bulbs as small, hard, black bodies (sclerotia) which are about one-sixteenth of an inch in diameter. Lesions are produced on the bulb under these bodies.

The lesions or spots are brown and usually round and are generally less abundant on either end of the bulb.

Small, elongate, yellow spots are produced on the foliage, which later become white with a brown tinge. These spots are surrounded by tissue that has a watery appearance. They enlarge and coalesce and often infect the entire leaf.

On the stalks the lesions are small, brown and surrounded by a water-soaked area. These lesions may be produced anywhere on the stalk, where they penetrate into the stem and cause it to weaken. The plants fall over if the fungus enters at the base or the flower may topple over if penetration is higher up on the stalk.

No fungicide for spraying foliage or solution for sterilization of bulbs has been found. It is recommended that only clean bulbs be planted. Care in handling bulbs and proper storage conditions will materially check the disease. All diseased plants should be raked and burned in the fall.

VIOLET, *Viola odorata*

LEAF SPOT attacks the violet plants at any stage of growth thruout the growing season. It is caused by a fungus. Rapidly growing plants are most susceptible to leaf spot. It appears on

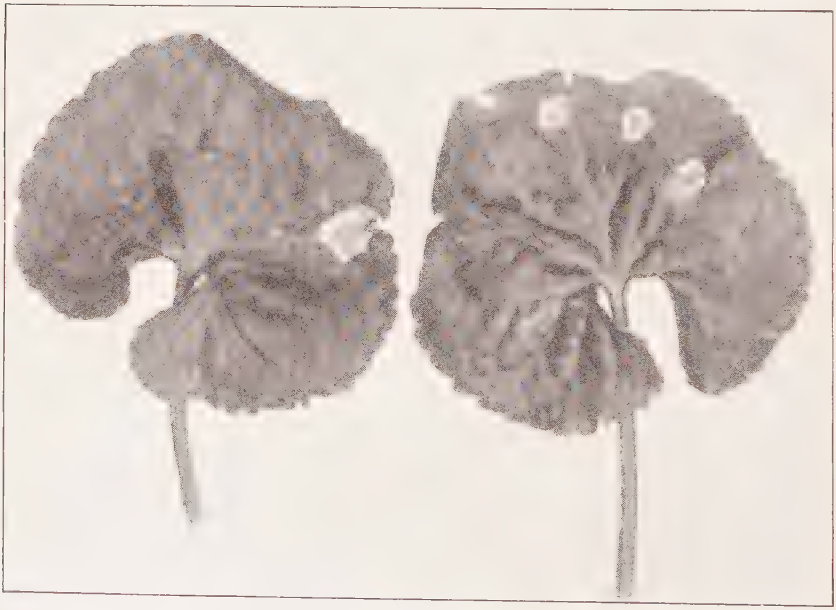

Fig. 14. Leaf spot of violet.

the leaves as small, round, yellowish spots (Fig. 14). The spots are usually surrounded by a narrow ring of discolored tissue. This surrounding tissue is usually dark at first, but soon changes to a lighter color with age. The spots coalesce until often the entire leaf is destroyed.

Sprays of any kind are of little or no value in controlling this disease. Care should be taken to use only healthy plants for propagation. Greenhouses and frames should be kept clean and well airated. All diseased leaves should be picked and destroyed.

Virginia Creeper, *Ampelopsis quinquefolia*

Leaf Spot.—The disease is caused by a fungus *(Phyllosticta viticola)*. Leaf spot is very common on Virginia creeper and is most abundant on foliage above 6 or 8 feet from the ground. Circular, dead, brown spots are produced on the leaves. These spots are about one-quarter to one-half inch in diameter. In severe cases the leaves turn yellow, wilt and eventually fall. It can be controlled by the same method as for leaf spot on peony.

Zinnia, *Zinnia elegans*

Leaf Spot.—Zinnia plants are generally quite free from disease in Colorado, but occasionally they are affected with a leaf spot. This disease is caused by a fungus *(Cercospora atricincta)*. It is characterized by the presence of small irregular, angular spots on the foliage. These spots are grayish and have a definite brown border.

The control for this disease is the same as for leaf spot of violet.

Damping-off

A number of ornamental plants are subject to damping-off. The disease affects the plants in the seedling stage, causing them to rot off at the surface of the ground. The stems appear water-soaked and soft and the plant collapses and falls over on the ground.

The disease is caused by several soil fungi. These fungi live indefinitely in the soil and grow best in wet, warm soil. Damping-off usually occurs in seedbeds where the plants are crowded and the soil is too wet. Slow-drying soil and poor ventilation of the greenhouse or cold frames are conducive to the disease.

In controlling damping-off the first preventive measure is to get rid of surface moisture on the soil. Ventilation and spacing of plants or a thin layer of sand on the soil will tend to keep the surface of the soil dry and produce conditions unfavorable for the growth of the fungus.

Soil sterilization is effective in combating the disease; formaldehyde or heat may be used for this purpose.

The formaldehyde treatment consists of sprinkling the loosened soil with a solution of formaldehyde, 1 gallon to 50 gallons of water. Sprinkle 1 gallon of this solution to a square foot of the soil and then cover plot for 12 hours. Planting should not be made in the soil for 10 days after treating.

In a similar way copper sulphate or blue vitriol may be applied. One pound of the sulphate is dissolved in 25 gallons of water and applied at the rate of 1 pint to a square foot of ground. An equal amount of water should then be sprinkled on the soil to wash the copper into the ground.

Soil sterilization by heat is the most successful method of destroying the damping-off fungus. This can best be accomplished by turning live steam into an inverted iron pan over the seedbed. The soil is exposed to the steam for one-half to one and one-half hours. In testing the efficiency of the treatment, a potato may be buried in the soil 4 or 5 inches deep; the time necessary to cook the potato is enough to kill the damping-off fungi.

Steam pipes furnish a very satisfactory method of soil sterilization. The pipes are connected to a header or lead pipe direct from a boiler. Holes of about $\frac{5}{16}$-inch diameter are bored in the pipes 6 inches apart and the steam escaping from these thoroly heats and sterilizes the soil. Smaller holes than $\frac{5}{16}$inch tend to plug up and prevent the escape of steam. A low-pressure boiler of large capacity is most suitable for this work. Steaming should continue for two hours. (See Experiment Station Bul. 321.)

FUNGICIDES

1. BLUE VITRIOL-COPPER SULPHATE.—Copper has a very specific action on fungi and may be used in the form of copper sulphate for sterilizing cold frames, washing greenhouse walls, benches, etc.

Copper sulphate, 2 to 3 pounds.

Water, 50 gallons.

Dissolve the copper in a little hot water and then dilute to 50 gallons.

2. BORDEAUX MIXTURE.—a. Home-made. This consists of blue vitriol, lump lime and water in the following proportions: Blue vitriol (copper sulphate), 4 pounds; unslaked hot lime, 4 pounds; water, 50 gallons. This is known as a 4-4-50 mixture. The best

way to prepare home-made bordeaux is to dissolve the blue vitriol in 25 gallons of water. The chemical dissolves quickest if suspended in a sack at the top of the barrel or tank holding the water. Slack the 4 pounds of lime in just enough water to slack it well and mix with 25 gallons of water. Pour simultaneously the 25 gallons of blue vitriol solution and the 25 gallons of lime solution into a third barrel or tank. This insures thoro mixing and gives an excellent suspension of the small lime particles.

For convenience, the following method can be used in making home-made Bordeaux. This method results in about as good a mixture as the one just described. The blue vitriol is dissolved in 40 gallons of water the same as described in the above method. The lump lime is slacked in a small quantity of water and poured into the blue vitriol solution. Then enough water is added to bring the liquid up to 50 gallons.

b. Dry Bordeaux.—This is a commercial preparation of lime and blue vitriol. It is dissolved in water direct from the package. Directions for mixing are found on the container. Dry bordeaux is very useful for gardens where but a small amount of spray is needed.

3. AMMONIACAL COPPER CARBONATE.—Bordeaux mixture discolors the leaves; therefore ammoniacal copper carbonate is recommended in its place, since it will not remain on the foliage. This fungicide is very strong and should always be tested on a few plants.

Ammoniacal copper carbonate is prepared as follows:

Copper carbonate	6 ounces
Ammonia (26° Baume)	3 pints
Water	50 gallons

The ammonia is diluted with about 2 gallons of water and the copper carbonate is made into a paste with a small quantity of water. These two are mixed and enough water added to make 50 gallons. This fungicide loses its strength rapidly and should be used immediately.

4. POTASSIUM SULPHIDE.—This chemical is effective in controlling the powdery mildews, altho it is not as effective as copper sprays for other fungi. It is prepared in the following proportions:

Potassium sulphide	3 ounces
Water	10 gallons

The spray should be prepared fresh each time it is to be

used. In the greenhouse a weaker mixture should be used, as the above strength tends to burn the young leaves.

5. SULFUR. (a) Flowers of Sulfur.—This is the ordinary yellow sulfur obtainable at any drug store. It is a very effective fungicide, being particularly useful for the powdery mildews. It should be dusted on in the early morning when dew is present.

(b) Atomic Sulfur.—This is a commercial preparation, more finely powdered than the flowers of sulfur, and is also more effective. It may be mixed with water and used as a spray, as well as in the dust form. This dust is so fine that it tends to lump and clog without a filler. When lime is mixed with sulfur as a filler the proportion varies from 50 to 90 percent sulfur, depending on the severity of the disease.

(c) Sulfur Plus Five Percent Potassium Permanganate.—Recent work on sulfur as a dust has shown that the addition of 5 percent potassium permanganate will hasten the action of the fungicide. While this mixture has not been tried on ornamental plants, it is mentioned as a possible dust for controlling mildews and some rusts.

6. SPREADERS.—Frequently fungicidal sprays do not stick well to plant leaves, but tend to collect in drops and run off. Several materials are useful to hold the spray on the leaves. These spreaders or stickers also tend to make the spray film thinner and are economical to use. Moreover, they hold the spray on the leaves for a longer time and prevent washing off by rain.

Common laundry soap shaved up and dissolved in spray solution makes an effective sticker. Skim milk has a similar effect. Commercial preparations of casein are also very effective as spreaders. Rosin and fish-oil soap are also boiled together and used as a sticker for fungicides.

NOTE: The approximate prices on the above-mentioned substances are listed below:

Copper sulphate	$0.15	per pound
Dry Bordeaux	.20	" "
Corrosive sublimate	2.70	" "
Formaldehyde	.24	" "
Sulfur—flowers	.10	" "
Rolled	.06	" "
Precipitated	.35	" "
Fish-oil soap	.25	" "
Rosin	.15	" "
Kaso (commercial casein preparation)	.20	" "

DIRECTIONS FOR SENDING PLANTS FOR IDENTIFICATION

1. Send plenty of material. Send roots, stems and leaves of a diseased plant. It is difficult to properly identify a disease in many cases from fragments of a plant.

2. When sending soft-tissue plants, press out the leaves and wrap in oiled paper or moist newspaper, and then heavy dry wrapping paper, or put in a box. Mail as soon after gathering as possible.

In this way plants will arrive in good condition. Do not crowd a wad of the plant into an envelope for sending. Such material always arrives in poor condition and it is difficult or even impossible to identify.

3. When sending specimens of woody plants, collect material which shows not only the diseased portion, but adjacent healthy parts.

4. Send all material to:

Department of Botany,
Colorado Agricultural College,
Fort Collins, Colorado.

BULLETIN 352 MAY, 1929

THE SULPHIDE SULPHUR CONTENT AS A BASIS FOR DILUTING LIME-SULPHUR FOR SPRAYING

BY GEO. M. LIST

COLORADO AGRICULTURAL COLLEGE
COLORADO EXPERIMENT STATION
FORT COLLINS

The Colorado Agricultural College

FORT COLLINS, COLORADO

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THE SULPHIDE SULPHUR CONTENT AS A BASIS FOR DILUTING LIME-SULPHUR FOR SPRAYING

BY GEO. M. LIST

While lime-sulphur is being replaced to some extent by other contact sprays in the control of certain pests, it remains one of our very important insecticides. The proper dilution of the concentrated forms is of prime importance and errors in this connection may explain some failures to get satisfactory results.

Dilutions for spraying have been based upon work at the New York (Geneva) Agricultural Experiment Station, which indicated that the dormant spray for San Jose scale should contain about 0.297 pounds of sulphur in solution and the summer spray 0.065 pounds. The percentage of sulphur in solution is ordinarily determined by the specific gravity method, the Baume scale generally being used. The density of the diluted spray as called for in most tables of dilutions is about 4.6 degrees Baume, or 1.0327 specific gravity, for a dormant strength and 1.0 degree Baume, or 1.0072 specific gravity for summer spraying.

This method, while simple and convenient, does not take into full consideration that all sulphur in solution may not be in the most active form and that the presence of many other materials in solution may affect the specific gravity.

Shafer (1) in 1911 determined that the effectiveness of lime sulphur as a contact was largely due to the ability of certain compounds in it to take up oxygen. He states that "Two properties—strong reducing power (i. e. great affinity to take up large amounts of oxygen) together with the ability to, at first, soften or partially dissolve the newly secreted wax at the margin of the scale—appear to be the most important in making lime-sulphur an efficient scalecide."

Tartar (2) states that "The compounds formed by the reaction between calcium hydroxide and sulphur, under ordinary commercial conditions of manufacture, are calcium tetrasulphide, pentasulphide, thiosulphate and sulphite. All of these compounds are readily soluble in water with the exception of the sulphite, which is comparatively insoluble, * * * * in general, the insecticidal properties of lime-sulphur are due principally to the following named properties:

The writer is indebted to Prof. Earl Douglass, of the Chemistry Dept., Colo. Agr. Expt. Station, for assistance in making the testing fluid, and for reading the manuscript of this paper.

"(1) Its power to take up large amounts of oxygen, (2) its ability to soften the newly secreted wax at the margin of scale insects, and (3) the amount of free sulfur formed in its decomposition. If this be true, then the question of the correct valuation resolves itself into the quantitative measurement of these factors.

"The amount of oxygen consumed depends upon reactions as represented in the following equations:

$$CaS_5 + 3O = CaS_2O_3 + 3\,S$$
$$CaS_4 + 3O = CaS_2O_3 + 2\,S$$
$$CaS_2O_3 = CaSO_3 + S$$
$$CaSO_3 + O = CaSO_4$$

"The combination of oxygen with the moist polysulphides is very rapid and quantities of the tetrasulfide or pentasulfide containing the same amount of calcium would absorb the same amount of oxygen and consequently produce the same amount of thiosulfate. This last named substance decomposes very slowly under ordinary conditions. For this reason, calcium sulfite is formed very gradually and the oxygen required to form the sulfate is absorbed slowly,—too slowly, in the writer's opinion, to make it of insecticidal importance. Investigations made by the entomologist of this station indicate that calcium sulfite has practically no insecticidal effect upon San Jose scale."

The above equations, besides showing the amount of oxygen consumed indicate the power of the various compounds to liberate free sulphur, the majority of it coming from the polysulphides.

In regard to the ability of lime-sulphur to soften the scale covering of San Jose scale Tartar (2) states:

"The writer's experience in handling the spray simply verifies the correctness of Shafer's statement that 'the so-called caustic action of the wash on the hands seems rather due to its strong reducing power (power to absorb oxygen) than to the alkalinity of the solution.' It is quite possible that this reducing power may also cause the softening of the so-called wax on the scale insects. If this be true, the 'oxygen' number mentioned above would give its quantitative measurement. At any rate, the power of the spray to soften the so-called wax is evidently due to some property of the polysulfides; and in the light of present knowledge no definite statement can be made regarding its exact nature or its exact quantitative analytical measurement."

In 1924 Abbott, Culver, and Morgan (3) tested against San Jose scale, solutions made up to correspond to the various com-

pounds of lime-sulphur that might possibly have insecticidal value namely, calcium trisulphide, calcium tetrasulphide, calcium pentasulphide, calcium thiosulphate, calcium sulphite and sulphur. Their conclusions were that "Calcium thiosulphate, calcium sulphite and free sulphur were of no practical value."

The virtues of lime-sulphur as an insecticide, therefore, appear to lie in the so-called polysulphides, namely, calcium pentasulphide, calcium tetrasulphide and calcium trisulphide. The last named is least effective and fortunately forms only a small part of most liquid lime-sulphurs.

This value of the polysulphides, which are often spoken of on the basis of the sulphide sulphur present, has long been recognized in the preparation of sheep and cattle baths for the control of external parasites. Chapin (4) states: "Lime sulphur dipping baths, whether home made or proprietary, are essentially composed of two substances in solution, both of which contain sulphur, namely, calcium polysulphide and calcium thiosulphate. The Bureau of Animal Industry has no present proof that calcium thiosulphate is of any value for the treatment of scabies in either cattle or sheep, and pending further investigations, accordingly, must attribute the efficiency of dipping baths solely to the sulphur present in the form of calcium polysulphide."

The standard called for by the U. S. Bureau of Animal Industry for the dipping of sheep is a sulphide sulphur content in the prepared bath of 1.5 percent for sheep and 2 percent for cattle. In order to check frequently and quickly upon the sulphide sulphur content of stock baths, Chapin (4) has developed a rather simple iodine test that probably has a place in the evaluating of lime-sulphurs for spraying purposes. This, while probably not as accurate as the official methods of chemical analysis, has proved satisfactory in checking the strength of dipping baths and these must be much more accurately controlled than have been the strengths of tree sprays. The test is used by some manufacturers of lime-sulphur in establishing the strength of their material, as a basis for their guarantee for stock dips.

AN OUTLINE OF THE TEST

The following brief outline of the iodine test is made from Chapin's (4) original description of it.

The test is based upon the reaction between sulphides and iodine in neutral solution, whereby sulphur is precipitated and metallic iodide formed. It therefore, directly estimates, not the sulphur, but the metal calcium, combined with the sulphur in

the polysulphides. The sulphur present can be accurately computed only when the sulphur and calcium are combined in unvarying proportions. Theoretically this requirement is not met in the case of lime-sulphur, but experience has shown that the variation in the carefully made liquid products is not so great but what the test is sufficiently accurate for practical purposes. The ratio provisionally adopted by Chapin is 4.6 atoms of sulphur to each atom of calcium, or by weight, 147.5 parts sulphur per 40.07 parts calcium. Since Chapin arrived at this ratio, Abbott, Culver, and Morgan (3) have stated that in more than 100 commercial lime-sulphurs analyzed the ratio was 4.68.

The test is made by adding standard iodine solution to a measured quantity of diluted lime-sulphur until the resulting liquid no longer gives color with a dilute alkaline solution of sodium nitroprussid, showing that calcium polysulphide has been entirely decomposed. The amount of iodine added to reach this point is then a measure of the amount of "sulphide sulphur." The test fluid is of such strength that, in the actual performance of the test, each cubic centimeter of it employed represents one-tenth of 1 percent of sulphide sulphur when the amount of lime-sulphur used is 24 cubic centimeters. The directions for making the test fluid and indicator solution, as given by Chapin (4) are as follows:

"In preparing it, 44 grams iodin and 88 grams potassium iodid are dissolved in water and made to 1 liter, and the strength of the solution is then adjusted against sodium thiosulphate or arsenious oxid. For example, 50 c.c. of a tenth-normal solution of either of the above standards should require 15.38 c.c. of test fluid of correct strength. The test fluid should, of course, be kept in glass-stoppered bottles only, and in a dark, cool place.

"The tablets for indicator solution are prepared after the following formula:

	Grams
Milk sugar, powdered	12
Sodium nitroprussid, powdered	20
Sodium carbonate, monohydrated, powdered	100

"Mix, moisten with 50 percent alcohol, granulate, and dry at room temperature, then mix granules with 3 percent of powdered talcum and compress to tablets of 0.255 gram."

The indicator solution is made ready for use by dissolving 1 tablet in 15 c.c. of water. This should be kept in amber glass, since it is rapidly decomposed upon exposure to light.

If the test is to be used for concentrated solutions they should first be diluted with sufficient water to bring the sulphide sulphur content to not much over 2 percent.

Chapin (4) describes the equipment and technique for making tests in the field. The ordinary titration equipment and technique seem to be more practical and accurate when they can be used.

RESULTS OF TESTS

Table 1 gives the results of this test upon a number of typical samples of commercial and home-made lime-sulphurs. It will be seen that the sulphide sulphur content varies a great deal. This however, is not as important as the ratio of the sulphide sulphur content to the specific gravity, which indicates the presence or absence of other compounds that affect the specific gravity and which we must consider as inactive as insecticides. Samples 1 to 16 inclusive are of commercial brands of lime-sulphur now on the market as tree sprays and stock dips. Their ratio of sulphide sulphur to specific gravity is rather high, the average being .961, the lowest .917 and highest .985. Samples 17 to 40 inclusive are "home made." Seventeen to 28 inclusive were made in a community plant at Paonia, Colo., where live steam is used in the cooking. Twenty-nine to 40 inclusive were made by direct heat in open kettles. The ratio of sulphide sulphur to specific gravity in these home-made materials is considerably lower, showing the presence of other compounds in solution that affect the specific gravity. The average ratio is .677, the minimum .604 and maximum .768.

Column 7, Table 1, gives in percentage the sulphide sulphur content of the samples when diluted to a strength called for, by standard specific-gravity-dilution tables for San Jose scale spraying. This indicates the variation in the amount of active ingredients that may exist with this system of dilution. The range is from 2.288 to 3.847 percent, or, in other words, the former has only 59 percent as much active ingredients as the latter. The average sulphide sulphur content of all commercial brands so diluted was 3.51 and of all home made, 2.70 percent, or 77 percent of the former. All tests were made of the clear liquid only.

Column 6 gives the gallons of concentrate called for by the specific gravity dilution tables to make 100 gallons of spray and column 10 the gallons required to make 100 gallons of spray having a sulphide sulphur content of 3.35 percent, which appears to be an effective strength. Only two samples of the commercial material failed to show this sulphide sulphur content

and their variation from this was only slight while all the other samples failed by considerable amounts, one sample being as low as 2.288 percent. This would be only 68 percent of a 3.35 percent standard. The average of all the home-made materials was only 80 percent of this standard.

EFFECTIVE AMOUNTS OF SULPHIDE SULPHUR.—There is little experimental evidence to establish the amounts of suphide sulphur that the sprays should carry to be effective against the various pests. Three samples that were analyzed and tested against the San Jose scale by Abbott, Culver and Morgan (3) can be calculated to have carried 3.20, 3.30 and 3.31 percents respectively. According to Parrott a gallon of diluted lime-sulphur for San Jose scale spraying should contain 4.75 ounces of sulphur in solution, or 3.45 percent, for blister mite spraying, 3.56 ounces or 2.60 percent, and for summer spraying, 1.04 ounces or .0775 percent. Holland, Bourne and Anderson (5) state that the ratio of thiosulphate sulphur to polysulphide sulphur in commercial lime-sulphur liquids is one to 32. By correcting Parrott's figures for the sulphur in solution by deducting the thiosulphate sulphur, we would have a requirement of 3.35 percent of sulphide sulphur for San Jose scale, 2.55 percent for blister mite and .75 percent for summer spraying. These figures come within the range of the sulphide sulphur content of effective dilutions generally used, so are therefore suggested for use when dilutions are based upon the sulphide sulphur content.

Table 2 gives the dilutions for concentrates of 4 to 35 percent sulphide sulphur content.

PRACTICAL USE OF THE TEST

The test is sufficiently simple that it can be used by any fieldman and can be adapted to use in the orchard. The individual growers will not use it as freely as the Baume test, but few individuals are making their own solution. Most home-made materials are made in community plants. It would not be difficult for some careful workers in connection with these to learn the test. The commercial concentrates, if shipped under a sulphide sulphur guarantee, could be more accurately diluted than by the specific gravity basis.

The greatest error in diluting by the Baume test occurs with the home-made concentrates. This error, on the average, appears to be about 25 percent when the clear liquid is used. If the sludge is also included, the error is greater, as this must be considered as practically inert as an insecticide and therefore dilutes the active material. The amount of sludge varies a great

deal, depending upon a number of factors such as proportion of ingredients, their purity, method and time of cooking, etc.

Quaintance (6) states: "In spraying for San Jose scale and the pear-leaf blister mite about 5 percent more of the solution should be used than the table of dilutions indicates, if the sludge has not been filtered out. In summer spraying, however, no allowance for sludge is necessary, as a large percentage of this is composed of finely divided sulphur, which is of value."

If the dilutions by Baume of the clear liquid from home-made materials are 25 percent below a desired content of sulphide sulphur and the sludge is also used and dilutes to the extent of 5 percent, it would appear that, if these dilution tables are used, the amounts called for should be increased by 30 percent.

DRY LIME-SULPHUR

The iodine test for sulphide sulphur directly estimates the calcium of the polysulphides, not the sulphur itself. The amount of sulphide sulphur is arrived at thru the knowledge that there is a rather constant ratio of calcium to sulphur in the polysulphides in liquid lime-sulphurs made by standard formulas under the usual conditions of cooking. The ratio provisionally adopted is 4.6 atoms of sulphur to each atom of calcium. Abbott, Culver and Morgan (3) state:

"Based on the analyses of more than 100 commercial lime-sulphur solutions the average molecular ratio $\frac{\text{Polysulphide sulphur}}{\text{Polysulphide calcium}}$ is 4.68, indicating a predominating percentage of the higher sulphide, CaS_5, whereas from the analyses of 38 samples of dry lime-sulphur the molecular ratio $\frac{\text{Polysulphide sulphur}}{\text{Polysulphide calcium}}$ is 3.53, indicating that the polysulphides are mainly the lower sulphides, CaS_4 and CaS_3.

"When the water is removed from liquid lime-sulphur to produce the dry calcium-sulphur, the calcium polysulphides are changed from the mixture of polysulphides 5 (CaS_5) and 4 (CaS_4) with the 5 predominating, which is found in liquid lime-sulphur, to a mixture of polysulphides 4 (CaS_4) and 3 (CaS_3) in approximately equal proportions. This change would, according to the experiments given in Table 10, reduce the effectiveness of the dry calcium sulphurs since the higher polysulphides were found to be more effective than the lower ones."

In the light of this it can be seen that the test is not accurate for dry lime-sulphur preparations. It overestimates the sul-

phide sulphur content, apparently, to the extent of about 25 percent, and the sulphide sulphur present is less effective since the lower polysulphides are the least effective. These statements are borne out by the results obtained by Abbott, Culver and Morgan (3) in testing the dry lime-sulphurs against San Jose scale. They concluded that even the excessive amount of 33 pounds to 50 gallons of water did not serve as an effective remedy against this scale.

The writer has, however, calculated the sulphide sulphur content of several samples of dry lime-sulphur by the iodine test without making any corrections for the lower ratio of the calcium and sulphur in the polysulphides of these materials. These results are given in Table 3 along with the dilutions necessary to give a sulphide sulphur content called for in San Jose scale and summer spraying. These dilutions are not given as suggestions of the amounts of these materials to use because of the over estimation of the sulphide sulphur. Also Abbott, Culver and Morgan (3) have shown that an increase of the amount to the point where the usual amount of sulphide sulphur is present does not give effective control of San Jose scale due to the lower effectiveness of the lower polysulphides and to an apparent decreased effectiveness caused by the presence of considerable amounts of insoluble sludge. The dry lime-sulphurs are, therefore, considered impractical as insecticides under ordinary conditions. The work of Abbott, Culver and Morgan (3) indicates that the same is true of the sodium and barium sulphurs.

SUMMARY

All experimental data indicate that the insecticidal value of lime-sulphur is largely, if not wholly, due to the ability of the calcium polysulphides in it to take up large amounts of oxygen.

The Baume hydrometer test is not always an accurate method of measuring the amount of polysulphides in a solution. The presence of other soluble compounds affect the Baume reading.

The iodine test for the sulphide sulphur seems to be more accurate than the Baume reading.

The ratio of the sulphide sulphur content of samples tested to their Baume reading varied from .604 to .985. The ratio was higher in commercial samples than in home made.

The effective amount of sulphide sulphur in the dilute spray seems to be 3.35 percent for San Jose scale, 2.55 percent for blister mite and .75 percent for summer spraying.

The commercial samples, with the exception of two, when diluted according to the standard Baume dilution tables, carried

the specified percentages of sulphide sulphur. Some carried more than these percentages. The samples of home-made material carried from 68 to 88 percent of the specified amounts.

The error in diluting home-made lime-sulphurs by the Baume tables appears to be about 25 percent when sludge is not included. The presence of the sludge increases the error by another 5 percent.

The iodine test overestimates the sulphide sulphur content of dry lime-sulphurs. These materials, when diluted according to their sulphide sulphur content, become impractical as insecticides.

LITERATURE CITED

(1) SHAFER, GEO. D.
How Contact Insecticides Kill.
Technical Bulletin No. 11, Mich. Agr. Exp. Station

(2) TARTAR, H. V.
Chemical Investigations of the Lime-sulphur Spray.
Research Bulletin No. 3, Oregon Agr. Exp. Station.

(3) ABBOTT, W. S., CULVER, J. J. and MORGAN, W. J.
Effectiveness against San Jose Scale of the Dry Substitutes for Liquid Lime-sulphur.
U. S. D. A. Bulletin No. 1371.

(4) CHAPIN, R. M.
A Field Test for Lime-sulphur dipping baths.
U. S. D. A. Bulletin No. 163.

(5) HOLLAND, E. B., BOURNE, A. I. and ANDERSON, P. J.
Insecticides and Fungicides.
Mass. Agr. Exp. Station Bulletin No. 201.

(6) QUAINTANCE, A. L.
The San Jose Scale and its Control.
Farmer's Bulletin 650, U. S. D. A.

Table 1. Sulphide Sulphur Content and Dilutions of Lime-sulphur Samples.

Sample Number	Density of Solution. Baume Degrees	Equivalent in Specific Gravity	Sulphide Sulphur Content. Percent (On volume)	Ratio of Sulphide Sulphur, Percent, to Degrees Baume	Dilution for San Jose Scale (on Baume) (1) For 100 gal. Spray use gallons of Concentrate	Sulphide Sulphur Content of Dilutions according to Baume	Dilution for Summer Spray (on Baume) (1) For 100 gallons of use gallons of Concentrate	Sulphide Sulphur Content of Summer Spray	Dilution to 3.35 percent Sulphide Sulphur Content for San Jose Scale. For 100 gal. Spray use Gallons Concentrate	Dilution to .75 percent Sulphide Sulphur Content for Summer Spraying. For 100 gallons of Spray use Gallons of Concentrate
1	33.1	1.296	30.5	.921	11.	3.355	2.5	.7625	10.98	2.45
2	33.7	1.303	31.5	.934	10.5	3.307	2.5	.7875	10.63	2.38
3	30.3	1.265	29.5	.973	13.	3.835	3.	.885	11.35	2.54
4	29.45	1.256	28.5	.967	13.5	3.847	3.	.855	11.75	2.63
5	33.1	1.296	32.4	.978	11.	3.564	2.5	.81	10.33	2.31
6	34.5	1.312	34.	.985	10.5	3.57	2.5	.85	9.85	2.20
7	34.25	1.309	33.1	.966	10.5	3.475	2.5	.827	10.12	2.26
8	33.6	1.302	32.5	.967	10.5	3.412	2.5	.812	10.30	2.30
9	32.5	1.289	31.3	.963	11.	3.443	2.5	.782	10.70	2.39
10	34.	1.306	31.2	.917	10.5	3.276	2.5	.78	10.73	2.40
11	32.25	1.286	30.6	.948	11.5	3.519	2.5	.765	10.94	2.45
12	34.45	1.311	33.7	.978	10.5	3.538	2.5	.842	9.94	2.23
13	33.	1.295	32.2	.975	11.	3.542	2.5	.805	10.40	2.32
14	32.8	1.293	31.9	.972	11.	3.509	2.5	.797	10.50	2.41
15	34.3	1.310	33.3	.970	10.5	3.496	2.5	.832	10.06	2.25
16	33.2	1.297	32.5	.978	11.	3.575	2.5	.812	10.30	2.30
17	25.5	1.214	18.21	.714	16.	2.913	3.5	.637	18.39	4.12
18	25.	1.209	17.47	.698	17.	2.969	3.5	.611	19.17	4.29
19	26.	1.219	18.21	.700	16.	2.913	3.5	.637	18.39	4.11
20	25.	1.209	17.37	.694	17.	2.952	3.5	.607	19.28	4.31
21	25.5	1.214	17.16	.672	16.	2.745	3.5	.600	19.52	4.37
22	26.5	1.224	17.69	.667	15.	2.653	3.	.530	18.93	4.23
23	26.	1.219	17.37	.668	16.	2.779	3.5	.607	19.28	4.31
24	29.	1.251	20.95	.722	13.5	2.828	3.	.628	15.99	3.57
25	25.5	1.214	17.37	.681	16.	2.779	3.5	.607	19.28	4.31
26	26.	1.219	17.69	.680	16.	2.830	3.5	.619	18.93	4.23
27	28.	1.240	18.95	.676	14.5	2.711	3.	.568	17.67	3.95
28	30.	1.262	21.90	.730	13.	2.847	3.	.657	15.29	3.42
29	27.	1.229	17.60	.651	15.	2.640	3.	.528	19.03	4.26
30	31.1	1.274	20.80	.668	12.	2.496	2.5	.520	16.10	3.60
31	30.3	1.265	20.2	.666	13.	2.626	3.	.606	16.58	3.71
32	24.5	1.195	15.	.612	17.	2.550	3.5	.525	22.33	5.00
33	25.	1.209	15.1	.604	17.	2.567	3.5	.528	22.18	4.96
34	29.8	1.259	22.9	.768	13.	2.977	3.	.687	14.62	3.27
35	28.5	1.245	18.2	.638	13.5	2.457	3.	.546	18.40	4.12
36	28.8	1.248	18.8	.652	13.5	2.538	3.	.564	17.81	3.98
37	28.5	1.245	20.4	.715	13.5	2.754	3.	.612	16.42	3.67
38	26.3	1.222	16.8	.638	16.	2.288	3.5	.588	19.94	4.46
39	29.8	1.260	20.2	.677	13.	2.626	3.	.606	16.58	3.71
40	29.6	1.257	19.6	.662	13.	2.548	3.	.588	17.09	3.82

(1) According to Table 1, "Standard Formula for Application," Mass. Agr. Exp. Station Bulletin No. 201.

Table 2. Dilution for Liquid Lime-sulphur to Give a Sulphide Sulphur Content of 3.35 percent for San Jose Scale, 2.55 percent for Blister Mite and .75 percent for Summer Spraying.

Percent sulphide sulphur content of concentrate (on volume)	Dilution for San Jose Scale. To one gallon concentrate add gallons water	Dilution for San Jose Scale. For 100 gallons of spray use gallons of concentrate	Dilution for blister mite. To one gallon of concentrate add gallons of water	Dilution for blister mite. For 100 gallons of spray use gallons of concentrate	Dilution for summer spray. To one gallon of concentrate add gallons water	Dilution for summer spray. For 100 gallons of spray use gallons of concentrate
35	9½	9⅝	12¾	7¼	45¾	2⅛
34	9⅛	9⅞	12⅜	7½	44½	2¼
33	8⅞	10⅛	12	7¾	43	2¼
32	8½	10½	11½	8	41¾	2⅜
31	8¼	10¾	11⅛	8¼	40½	2⅜
30	8	11⅛	10¾	8½	39	2½
29	7⅝	11½	10⅜	8¾	38	2⅝
28	7⅜	12	10	9⅛	36½	2⅝
27	7	12⅜	9½	9½	35	2¾
26	6¾	12⅞	9⅛	9¾	34	2⅞
25	6½	13⅜	8¾	10¼	32¼	3
24	6⅛	14	8½	10½	31	3⅛
23	5⅞	14½	8	11	30	3¼
22	5⅝	15¼	7⅝	11½	28½	3⅜
21	5¼	16	7¼	12¼	27	3½
20	5	16¾	6⅞	12¾	25½	3¾
19	4⅝	17⅝	6½	13½	24½	4
18	4⅜	18⅝	6	14¼	23	4⅛
17	4⅛	19¾	5⅝	15	21½	4½
16	3¾	21	5¼	16	20	4⅝
15	3½	22⅜	4⅞	17	19	5
14	3⅛	24	4½	18¼	18	5¼
13	2⅞	25¾	4⅛	19½	16	5¾
12	2⅝	28	3¾	21¼	15	6¼
11	2¼	30½	3¼	23¼	14	6¾
10	2	33½	3	25½	12½	7½
9	1⅝	37¼	2½	28½	11	8¼
8	1⅜	42	2⅛	32	10	9¼
7	1⅛	48	1¾	36½	8	10¾
6	¾	56	1¼	42½	7	12½
5	½	67	1	51	5½	15
4	¼	84	½	64	4	19

Table 3. Sulphide Sulphur Content of Dry Lime-sulphur Products and the Dilutions Necessary to Secure a Sulphide Sulphur Content of 3.35 percent for San Jose Scale and .75 percent for Summer Spraying.

Sample No.	Sulphide sulphur content. Percent	Dilution for San Jose scale: For 100 gallons of spray use pounds of concentrate	Dilution for San Jose Scale: For 1 gallon of Spray use ounces of concentrate	Dilution for Summer Spray: For 100 gallons of Spray use pounds of concentrate	Dilution for Summer Spray: For one gallon of Spray use ounces of concentrate
1	60	46.5	7.44	10.4	1.66
2	57.2	48.8	7.80	10.9	1.74
3	63.2	44.2	7.07	9.9	1.58
4	63	44.3	7.08	9.9	1.58
5	58.2	48.0	7.68	10.7	1.71
6	61.2	45.6	7.29	10.2	1.63
7	65.2	42.8	6.84	9.5	1.52
8	60.2	46.4	7.42	10.3	1.64
9	59.2	47.2	7.55	10.5	1.68
10	60.6	46.1	7.37	10.3	1.64
11	64.8	43.1	6.89	9.6	1.53

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COST OF PRODUCING CROPS ON IRRIGATED FARMS

BY R. T. BURDICK AND H. B. PINGREY

In Cooperation with Division of Farm Management and Costs,
Bureau of Agricultural Economics, U. S. D. A.

COLORADO AGRICULTURAL COLLEGE
COLORADO EXPERIMENT STATION
FORT COLLINS

COST OF PRODUCING CROPS ON IRRIGATED FARMS

By R. T. Burdick and H. B. Pingrey

In the spring of 1922 the Colorado Agricultural Experiment Station in cooperation with the United States Department of Agriculture, began a detailed study of irrigation farming in Northern Colorado. Weld County was chosen because of the wide selection of enterprises possible in the area. The results of the first 4 years' work were published as Colorado Station Bulletin 318. The cost of producing crops, the reasons for variation in costs and the use of costs as a guide to future farming plans are discussed in this bulletin.

Precipitation.—The rainfall each month and yearly totals are shown in Tables 1 and 2. The Greeley and Windsor records are not available prior to 1924.

It is customary to rely upon rainfall during the spring months to give sufficient moisture to start crops. Consequently, when the spring rainfall is abnormal many seedings fail to germinate. The rainfall in April, 1925, was 0.1 inch in Fort Collins, .06 in Greeley and .05 at Windsor. Following that about 1 inch fell in May. The normal for these 2 months is 4.95 inches, while about 1 inch actually fell. By the time the farmers realized the situation it was so late that sugar beets would make a poor yield if they were irrigated up, so many acres were abandoned and put into other crops.

The rainfall by months is an example of the factors which farmers cannot control. In 1923 there was so much rain and snow in February, March and early April that all spring work was delayed. The other years were about normal for spring work.

Hail.—This section of Colorado suffers frequently from severe hail storms. These are usually local in nature, damaging only a few square miles at any one time. In 1922 one or two farms just starting in to keep records on this project were so severely hailed out that they withdrew. Other farms were hurt to a less extent.

Note: The authors wish to express their appreciation for painstaking work performed in computing these records by the following members of the research staff of the Department of Economics and Sociology: Edna Bigelow, Ethel M. Barnhart and Nan Paterson; also to two field men who assisted part of the time, George Knutson and Chas. H. Russell. The farmers who gave so freely of their time and patience in getting the field records deserve special mention. Without their aid this work could not have been done. The following had records one or more years: E. R. Bliss, R. Bliss, R. Clark, B. A. Colwell, O. Erickson, J. Flint, W. B. Gress, W. J. Harding, A. S. Harris, J. Haythorn, O. Hurick, T. Ireland, G. Johnson, J. Kaufman, E. J. Kellogg, A. D. King, A. Lair, R. E. Larkin, A. A. Leafgren, S. A. Lindblad, C. Magnuson, H. Magnuson, C. Meyer, J. Mills, W. H. Monfort, G. E. Nelson, J. McCullough, T. J. Nix, M. N. Robinson, C. H. Russell, J. Rutz, J. Thompson, J. Tinsman, G. P. Watson, R. Wilson, E. L. Wrignton.

A 16-ton beet crop secured by irrigating early in May, 1925.

In 1927 a very severe hail cut a swath from one end of the area to the other, damaging more crops than almost any hail storm on record. The men in this study were not in the direct path of this particular storm, but several of them suffered considerable damage.

Individual farms suffered damage from hail in other years—1923, 1924, 1925 and 1928.

Some farmers can count on being hailed out every year. Several men in this study were hailed out three different years so that crop yields were noticeably reduced. Few total crop failures resulted from hail except in the case of potatoes and grain.

Table 1.—Ten Years' Rainfall, Fort Collins, 1919 to 1928, Inclusive[1]

	PRECIPITATION										
Month	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	Normal
Jan. ...	T	0.54	0.96	0.35	0.19	0.51	0.27	0.25	0.04	0.26	.43
Feb. ...	0.30	0.64	0.19	0.53	1.39	0.54	0.09	0.28	0.40	0.52	.62
Mar. ...	1.65	0.14	0.13	0.36	2.74	1.83	0.58	1.54	1.87	1.38	1.01
Apr. ...	0.93	3.60	1.71	2.80	2.18	0.93	0.10	2.99	2.69	0.98	2.12
May ...	0.45	1.95	1.97	0.87	4.46	3.90	1.18	1.76	0.91	3.55	2.83
June ...	0.19	0.60	3.66	1.03	6.23	0.22	1.50	1.58	2.17	2.73	1.60
July ...	0.64	0.58	1.40	0.80	4.50	0.21	1.85	0.93	2.19	0.83	1.83
Aug. ...	0.61	1.72	2.55	0.73	0.62	0.05	1.32	0.86	2.10	0.69	1.19
Sept. ..	2.61	0.60	0.68	0.02	1.36	0.84	1.96	1.03	1.10	0.09	1.28
Oct.	1.93	0.50	0.37	0.74	3.55	0.78	3.26	1.15	1.05	1.50	1.16
Nov. ...	1.22	0.24	0.32	1.44	0.10	0.09	0.89	0.36	1.00	1.15	0.47
Dec. ...	0.39	0.54	0.89	0.31	0.25	0.74	1.50	0.83	0.25	0.06	0.49
Yearly	10.92	11.65	14.83	9.98	27.57	10.64	14.50	13.56	15.77	13.54	15.03
Percentage of precipitation of total Mar. to Sept. incl.)	64.8	78.8	81.7	66.2	80.1	75.1	58.5	78.8	82.7	74.2	78.9

[1]Robert E. Trimble, The Climate of Colorado, Colo. Bul. 340.

Table 2.—Five Years' Rainfall, Greeley and Windsor[1]

Month	GREELEY 1924	1925	1926	1927	1928	WINDSOR 1924	1925	1926	1927	1928
Jan.	....	.21	.27	T	.08	....	.15	.22	T	.15
Feb.	.49	.05	.25	.63	.15	.46	.01	.20	.47	.03
Mar.	1.45	.26	.35	1.75	.54	.88	.30	1.33	1.34	.65
Apr.	.84	.06	1.03	2.34	.87	.66	.05	1.67	1.32	.75
May	2.59	1.01	.97	.88	2.87	3.38	.98	1.88	.69	3.68
June	.38	3.09	1.44	2.78	6.04	.14	1.89	1.70	1.38	1.73
July	.05	1.76	1.82	2.29	2.78	.50	2.17	2.69	2.86	.78
Aug.	T	4.25	.59	1.32	1.39	.01	2.36	1.14	1.16	.38
Sept.	1.88	.22	.94	.46	T	1.76	2.12	.94	1.25	T
Oct.	1.04	3.05	1.71	.23	.51	1.00	2.01	1.02	.58	2.06
Nov.	....	.66	.55	1.50	1.05	.04	.43	.17	.79	.35
Dec.	.80	1.27	1.10	.05	.01	.37	.33	.84	.11	.05
Yearly	9.52	15.89	11.02	14.23	16.29	9.20	12.80	13.80	11.95	10.61

[1]Courtesy Great Western Sugar Company.

Irrigation

In general, water is supplied by irrigation companies to their share holders about May 1. No exact date can be secured since the moisture conditions in the valley and storage conditions in the mountains affect the initial delivery of water any particular year. Furthermore, there are some ditch companies that have direct appropriations from the main river during the entire season and make delivery of water a few days to a week previous to May 1.

The large ditch companies have, in addition to some direct appropriation from the river, storage facilities for late irrigation. Late irrigation, principally of row crops, begins about July 15. From this date on the main irrigation water supply is furnished by storage lakes and reservoirs which have been filled during the flood stage of the river. The discharge from the river varies from year to year and depends upon the amount of snow on the upper slopes of the drainage basin and upon the rapidity with which this snow melts.

History of Ditches[2].—The Larimer and Weld ditch was incorporated in 1879. Water rights call for a continuous flow of 144 second feet thruout the season when water is available in rivers. Considerable land under this system is susceptible to irrigation and as the supply tends to be limited, the value of irrigation stock has therefore increased considerably.

The carrying capacity of this ditch is 750 second feet. The main canal is 40 miles long. The canal is divided in to 3 sections. The company controls only the main ditch and delivers water to the laterals owned and controlled by separate companies. No records are kept of water delivered from direct appropriations.

[2]U. S. D. A. Bul. 1126, Irrigation in Northern Colorado, p. 30.

Storage or reservoir water may be drawn when 250 rights are called for and delivery stops when demand drops to 200 rights.

The Larimer County or Water Supply and Storage ditch was organized in 1880. The water supply direct from the river was not sufficient and steps were taken early in its history to construct storage facilities. In 1892 it was reorganized as the Water Supply and Storage Company with 600 shares. Assessments have been approximately $150 per share for the last 20 years. Recently this was increased slightly to complete another storage reservoir. The system includes 11 reservoirs with 4 canals tapping watersheds which are directed into the Poudre Valley shed. These waters are diverted into Chambers Lake, the present large storage reservoir. Water in this ditch runs continuously so long as there is water in the ditch for direct irrigation, that is, the flow of water is not intermittent after it is once determined when the water is to be turned out. The policy of the company has been to so gauge the flow of water during seasons by reducing the number of inches per share as to prolong the irrigation as climatic and seasonal conditions demand.

Pump Irrigation.—Irrigation by pumping is relatively unimportant in the Eaton and Greeley area. A few farms located west of Eaton and Greeley have installed wells from which irrigation water is pumped. The main reason why such wells are so few in number is the extremely high cost of digging and operating such wells and the risk that they may later cave with a complete loss of capital invested. A few wells for irrigation are found east of Eaton and near Galeton. In this section the water-table rises close to the surface and the cost of installation and operation is considerably less than that territory west of Eaton.

Pump irrigation has various economic aspects which should be given careful consideration. Water at any time may be had for irrigation and several hundred dollars may be made in a given year by being able to irrigate at the proper time. Especially is this true during dry seasons or a droughty spring. Furthermore, the water may be applied or withheld from any crop at the convenience of the producer. It often happens that some farmer may be decidedly busy with important farm operations which must be dropped for the time being in order to use ditch water for irrigation regardless of the actual need of his crops for moisture; otherwise the water is a total loss. He may not be able to secure water for a week or 10 days later and during a portion of this time the crops may have suffered considerably.

Irrigation Practice.—The effective use of irrigation water is one of the most important problems which confronts the farmers. As

the irrigated area tends to increase, the amount of available water per acre of irrigated land tends to decrease. It is therefore important that the farmer should have a knowledge of soil types, the water requirements of different crops, and finally, the proper time to apply water to each crop in order that the greatest yield be secured with the minimum amount of water.

The time of irrigation is largely influenced by the amount of natural precipitation which falls and its general distribution. Well-distributed showers during March and April are generally sufficient to germinate the seed and supply soil moisture until the early part of May. Careful preparation of the seedbed aids in preserving the soil moisture and making it available for plant growth. A definite plan of the farm operations aids the farmer in timely cultural practices which serve to conserve moisture for plant nourishment.

The application of water to crops is therefore in a sense within the control of the individual farmer. In another sense it is without his control in that the water is not available to the grower at such times and in such quantities as he may desire.

The practice of the irrigation companies is to turn water thru their ditches only after a certain number of shares have been ordered. This practice has been made necessary in order to escape as large a loss of water as possible by evaporation and seepage from the carrying canal or ditch. Therefore the availability of irrigation water is governed not by individual needs of any particular grower but by a group of growers. Local showers extending over a relatively small area of a few miles may supply sufficient moisture for a week in that area and yet crops may suffer for water in the surrounding area, in so far as the same ditch serves the two areas, because sufficient shares of water are not ordered in the company's office.

Influence of Soil on Irrigation Practice.—Soil type is also of importance. Some soils retain but a small portion of the water supplied to them. Sandy and gravelly soils are of this type. Crops on these soils may suffer severely unless lying under ditches that have early priority rights in the river. A knowledge of the distribution of natural precipitation in the early growing season and planting in accordance with the distribution and the general time of delivery of irrigation water will aid in eliminating any great and unnecessary risks.

The silt and clay soils being more retentive of the water applied need not have as frequent irrigations as the sandy soils. It is the need for more frequent irrigations upon sandy soils that has been of prime importance in the development of pumping plants. Practically all irrigation pumping has been developed on the lighter

soils. However, timeliness of plowing and other seedbed operations are highly important to successful farming and the distribution of the available supply of irrigation water thruout the season.

Time of Irrigating Crops.—Farmers have learned by experience when to apply water to crops to secure the greatest efficiency. This does not necessarily mean that all crops are irrigated at the proper time or at the critical period in the growth of the plant. What is meant is that farmers tend to irrigate those crops which make the best use of the water at the time it is available and at the same time allow for an even distribution of labor.

As a result alfalfa is the first crop to be irrigated. The earliness of the plant, the relatively large total leaf surface and rapid growth of the plant necessitate early application of irrigation water. Following the irrigation of the alfalfa crop small grains are irrigated for the first time at the jointing stage to secure the highest yield. Sometimes two irrigations are necessary, depending on climatic conditions. The second irrigation is generally at the filling stage. This irrigation may not be necessary some years for the crop itself but is made necessary if a succeeding stand of alfalfa is to be secured, the alfalfa being planted with the grain crop in the early spring. Too early irrigations at the germination or the filling stage produce a poor quality of grain.[1]

The irrigation of row crops, potatoes, beets and corn, as a general rule, begins in July and continues thruout the season at intervals of a week to 10 days apart until September. Corn is irrigated twice to three times, depending on climatic conditions. Beet and potato irrigation occurs at frequent intervals, depending on climatic conditions, type of soil and practice of irrigating, whether alternate rows or every row is irrigated. The common belief among farmers is that by withholding water from the beets, forcing the root to penetrate deeper, larger beets and increased tonnage is secured. This practice is questionable as it may result in a severe setback to the plant. It can be generally said that in so far as yield of beets depends upon irrigation practice and an optimum moisture content of the soil, the situation is largely within the control of the grower.

The first irrigation of potatoes after planting is generally at the time the tubers begin to set. This is largely dependent on climatic conditions affecting growth and date of planting. Infrequent rains after the tubers have set is desired by most potato growers inasmuch as they can control irrigations and thereby increase the quality of the tubers. A relatively dry period during the ripening stage

[1]Critical period of applying irrigation water to wheat. Kezer and Robertson. Journal of American Society of Agronomy, Vol. 19, No. 2, Feb. 1927.

is desirable since too great an amount of moisture results in a second growth which is detrimental to a high quality of potatoes.

Size of Farm

Table 3 shows the average areas of each farm for the period studied, with the area in each important crop. Corn, cabbage and peas were included in the column of miscellaneous crops. In most cases the size of farm was constant for the period. But in several cases the farm area was increased. The average shown for such farms is somewhere between the small and the large acreages that existed for individual years. Farms 11 and 17 increased their acreage, farm 13 both increased and decreased the acreage.

Five farms grew no potatoes during the period of this study. Three of these were on heavy soil, the other two had records for only 1 year.

Six men grew no sugar beets, largely for personal reasons.

The area of pasture is comparatively small. Many farmers have given permanent pastures serious consideration within the past few years since the alfalfa crop has tended toward lower yields. Some saving may be secured by planting 5 or 10 acres of permanent pasture inasmuch as the labor necessary to cut, rake, stack and haul alfalfa to stock kept in a dry corral is eliminated during the summer season. Furthermore, stock run on green pasture will not require the same amount of concentrates that is required on dry feed. Stock is also less subject to disease.

Little information of value concerning pastures was secured by the end of the year 1927. The general tendency seemed to be to pasture too soon and too heavy. On one farm the pasture was ruined by overgrazing. As experience is gained, undoubtedly permanent pastures will occupy a larger place in the plans of farmers in this area.

Table 3.—Average Area Each Crop Per Farm for Years 1922 to 1927 Inclusive

Farm No.	Number years	Total farm area	Crop area	Alfalfa	Barley	Oats	Wheat	Beans	Beets	Potatoes	Misc.	Pasture	Waste
1	5	79.4	75.72	27.46	3.90	7.20	3.31	.....	3.40	17.39	13.06	.74	2.94
2	4	81.1	72.27	23.46	.....	7.59	12.41	22.15	3.72	2.67	.26	1.93	3.15
5	6	159.07	150.75	44.87	13.77	.....	17.79	9.61	17.31	32.53	14.75	.....	8.32
6	4	121.57	97.94	30.69	.....	16.61	.....	15.84	.....	18.16	16.65	17.46	6.17
7	2	62.66	59.38	19.54	.....	.....	10.74	.....	5.61	9.16	14.31	.....	3.28
8	2	181.02	166.74	63.85	2.83	6.21	26.40	4.74	10.30	13.41	39.00	.....	14.55
11	6	139.63	135.60	42.30	.....	8.75	18.50	12.68	26.65	26.61	.08	.....	4.03
12	5	330.37	313.74	89.69	43.47	23.02	10.85	1.76	55.45	80.34	8.56	3.04	19.59
13	6	317.73	242.11	83.68	54.51	.41	.....	7.28	36.20	60.04	.....	.....	75.62[1]
14	3	229.93	219.13	77.35	22.69	4.28	20.42	7.61	34.77	29.18	22.87	.....	10.80
15	2	157.23	142.38	47.80	27.60	3.25	.....	.....	21.69	42.04	.....	.....	14.85
16	2	137.63	132.99	27.45	42.74	.....	.....	.....	22.02	40.78	.....	.....	4.64
17	6	208.31	193.21	73.58	50.48	11.36	1.35	8.64	42.04	4.91	.84	.53	14.74
18	2	92.99	88.45	32.77	22.76	.....	.....	.54	9.70	19.13	3.55	.....	4.54
20	3	184.95	165.00	52.27	17.78	1.33	22.58	2.00	48.63	14.64	5.74	.....	19.95
21	2	153.42	130.04	40.29	17.12	8.99	16.72	.....	.....	33.92	12.99	16.34	6.84
24	2	154.06	144.55	53.72	.....	.....	40.97	.....	.....	27.54	44.62	4.19	5.32
25	6	117.61	112.56	35.82	6.03	5.96	9.92	15.63	17.32	20.07	1.81	.....	5.05
26	6	153.59	138.58	37.93	18.39	14.60	6.86	4.82	29.56	23.94	2.67	8.46	6.55
27	6	112.43	74.44	18.33	13.41	.....	4.03	6.65	16.86	4.34	10.82	30.12	7.87
28	6	111.13	91.14	39.79	1.87	.....	16.16	.....	2.19	21.71	9.44	3.42	16.56
29	6	146.52	123.57	54.75	10.10	10.23	12.78	2.59	.....	26.58	6.56	11.75	11.20
31	4	204.24	192.47	66.58	7.99	8.51	10.62	9.87	52.97	30.84	5.08	3.87	7.90
32	1	158.57	152.24	30.69	33.12	27.55	.....	6.31	27.91	22.10	4.56	.....	6.33
33	4	160.75	151.17	66.00	19.50	2.16	.....	8.63	39.39	7.49	7.98	.45	9.13
34	4	160.14	143.27	36.41	36.54	.....	.....	.....	51.68	.....	13.64	11.57	5.30
35	2	180.00	144.49	71.09	12.36	.....	39.93	.....	16.06	.....	5.03	9.71	25.80
36	1	127.00	103.50	76.00	10.00	9.50	8.00	.....	.....	.....	.....	15.00	9.00
38	3	220.00	209.12	59.97	10.82	10.96	19.75	19.29	29.81	39.05	9.47	.....	10.88
39	3	80.00	78.15	6.40	9.75	7.83	2.23	2.67	24.62	14.41	10.25	.....	1.85
40	3	170.00	152.18	36.79	9.48	19.39	.....	.....	37.94	33.85	14.73	.....	17.82
42	2	80.00	78.56	38.20	13.05	1.86	6.01	.....	17.03	2.40	.....	.....	1.44
43	1	150.00	140.00	25.00	20.00	.....	24.00	.....	71.00	.....	.....	.....	10.00
45	1	115.76	111.87	.....	.....	40.02	.....	25.58	46.27	.....	.....	.....	3.89
	Percent		100.00	32.73	12.07	5.03	6.85	4.61	16.56	16.44	5.68		

[1]Includes land rented out.

Methods of Handling Factors of Cost

Man Labor.—The costs shown represent in each case the actual costs of man labor on the farms growing each crop. This method was followed because there was no basis upon which uniform rates could be developed at the start of the project.

The results on 123 total records for the period studied show that man labor cost 32.8 cents per hour. There was some variation from year to year. The highest yearly rate was in 1924 with 34.0 cents, the lowest was in 1927 with 29.92 cents. The variation between individual farms was widest in 1922 when one farm had a labor cost of 24.8 cents per hour while another farm showed a cost of 48.25 cents per hour. This was the highest rate on any farm any year.

These variations in the cost per hour of labor are due to many causes. Some farmers were able to hire help at lower rates per month; some paid high wages; some farmers worked long hours; some failed to report all their time on miscellaneous jobs around the farm; some hired almost all their labor; some did most of the work themselves. All these things affect the labor cost per hour. By using a uniform rate of 32.8 cents per hour for man labor in all the tables shown in this study, one can quickly note the effect upon total cost per acre or per unit of crop.

For the individual farmer there is a value in comparing his actual labor costs with the 7-year average. He can see whether his labor is costing more or less than is typical for the region. For example farm 5 had a labor cost per hour below the average each year for 6 years out of 7. The saving which he made amounted to $300 per year compared to labor at the average rate per hour or 11.16 percent less than the average cost on all farms. Farm 26 secured labor for $360 per year less than the average or 11.9 percent saving per year for the 7 years.

Contrasted with these two farms, farm 13 had a labor cost of $432 per year higher than the average of all farms, due to the fact that his cost per hour of man labor was 12.46 percent higher than the 32.8 cents average for all farms. Farm 28 had $190 more labor each year than the average or 15.46 percent increased labor cost per hour.

Farm 13 gets greater efficiency from labor because more time is spent in supervision of that labor. This becomes increasingly necessary as the size of plant or organization becomes greater or larger. Tools and machinery are kept in repair by the operator so that when hired men enter the field more ground is actually covered in a given time.

The actual cost per hour of man labor for each year is shown in Table 4. By comparing this rate with the 7-year average of 32.8

cents, one can find the saving or loss on each farm. Where labor rates are higher than the average they should be compared with the cost per hour of horse labor and then the total cost of man and horse labor per acre should be studied. A farmer with high costs per hour of man labor but with a low cost per acre is apparently using his labor more effectively.

In the case of farm 5, man labor cost 11.16 percent less per hour than the average on all farms. On the three crops—potatoes, sugar beets and alfalfa—the operator of this farm spent 7.3 percent more hours per acre than the average, making his actual labor cost in dollars just a little below average. Farm 13 had 12.46 percent more cost per hour of man labor than the average, but spent 19.8 percent less hours per acre on potatoes, sugar beets and alfalfa. The actual cost of labor per acre on these crops was less than the average. Apparently this operator used high-priced labor, but used it more effectively than the average.

Farm 26 had labor costs per hour 11.9 percent below the average. The hours per acre on potatoes, sugar beets and alfalfa were 16.8 percent above the average. Here was a case of low-cost labor, but to offset that more hours were required.

Table 4.—Cost per Hour of Man Labor for Each Farm Each Year Studied

Farm No.	1922	1923	1924	1925	1926	1927	1928
1	$.3213	$.3080	$.3846	$.5055	$	$	$ ....
2	.3963	.4613	.4340	.4265	....	....	....
5	.2655	.2426	.3080	.3116	.3061	.3085	.3108
6	.3177	.3441	.3490	.3500	....	....	....
7	.4065	.3867	....	....	....	....	....
8	....	.4100	....	.2810	....	....	....
9	.2480	....	....	....	....	....	....
11	.3581	.3056	.3074	.3682	.3361	....	....
12	.3303	.3204	.3520	.3809	.3360	....	....
13	.4825	.4015	.3618	.3591	.3785	.2982	.3423
14	.2934	.3513	.4260	....	....	....	....
15	.3673	.3129	.3300	....	....	....	....
16	.3515	.2726	....	....	....	....	....
17	.3153	.2963	.3054	.3540	.4155	....	....
18	.2892	.2882	....	....	....	....	....
20	.3461	.3446	.3240	....	....	....	....
21	.2495	.2429	....	....	....	....	....
24	.4392	.3076	....	....	....	....	....
25	.3193	.3455	.3056	.3537	.3811	....	....
26	.2930	.3164	.2611	.3165	.3227	.2358	.2729
27	.2549	.2466	.2831	.2739	.2764	.2404	....
28	.3809	.4104	.3906	.3699	.3660	.3711	.3563
29	.3810	.3747	.3687	.3846	.4470	....	....
31	....	....	.3179	.2563	.3110	....	....
32	....	....	.3996	....	....	....	....
33	....	....	.3621	.2491	.2987	.2964	....
34	....	....	.3936	.2552	.2810	.2868	....
35	....	....	....	.3587	.3820	....	....
36	....	....	....	.3442	....	....	....
38	....	....	....	.3878	.3450	.3578	.3271
39	....	....	....	.2765	.3220	....	....
40	....	....	....	.3146	.2150	.3177	.3092
42	....	....	....	....	.3350	.2333	.2295
43	....	....	....	....	.3580	....	....
45	....	....	....	....	....	.3106	....
Yearly Average	.3251	.3240	.3406	.3317	.3377	.2992	.3113

The farmers worked about 3,000 hours per man per year as shown by Table 5. A few men who did not feed livestock in the winter months worked less hours each. Practically all the men who made good profits worked long hours. Three thousand hours is equivalent to 25 days per month at 10 hours per day, or 300 days in a year. Few industries can show as high or uniform a labor record for their working force. This is one of the items that causes farmers to compare their business with industry, and ask why industry should pay better wages.

Table 5.—Hours Worked Per Man Per Year

Farm No.	1922	1923	1924	1925	1926
1	3516	3929	3528	2504	....
2	2436	2383	2387	2160	....
5	3153	3095	3556	3326	3355
6	2234	2456	2521	....	....
7	2208	....	....	....	....
11	3034	3407	3115	3110	3794
12	3343	3268	3322	3214	3143
13	2536	3021	2977	2893	3160
14	3463	....	2732	....	....
15	3159	3333	....	....	....
16	2434	....	....	....	....
17	3092	3277	3388	3286	2985
18	3755	....	....	....	....
20	3019	3075	3282	....	....
21	3622	....	....	....	....
24	2696	....	....	....	....
25	3305	3074	3130	2959	2886
26	3227	3382	3632	3309	3126
27	3931	3498	3678	3643	4097
28	2482	2413	2426	1521	2489
29	2468	2620	2200	2538	2765
31	....	....	3393	2760	3190
32	....	....	2641	....	....
33	....	....	3575	3743	3396
34	....	....	3227	3080	3263
35	....	....	....	3057	3190
36	....	....	....	2174	....
38	....	....	....	3647	3128
39	....	....	....	2874	4661
40	....	....	....	3137	3445
42	....	....	....	....	3407
43	....	....	....	....	3252
Average per farm	3005	3082	3090	2947	3302

Horse Labor.—The method of handling the cost of horse labor was the same as for man labor. The 7-year average on 123 records shows that an hour of horse labor cost 14.05 cents. The year 1925 had the highest rate of 15.36 cents and 1927 had the lowest of 11.99 cents. In 1922 the range in cost on individual farms was from 7.63 cents to 29.46 cents.

To a considerable extent this variation is due to the number of hours worked per horse. For the same four farms discussed under man labor, a 7-year average shows the following results:

Table 6.—Relation of Hours Worked Per Horse on 4 Farms to Cost Per Hour

Farm No.	Hours worked per horse	Cost per hour	Percent saving in horse labor compared to average	Percent extra cost of horse labor compared to average
13	1231	$.1143	18.84	....
5	982	.1279	9.19	....
26	735	.1869	....	32.75
28	493	.2130	....	51.30

Farm 13 saved $363 per year on horse labor when compared to average costs. Farm 5 saved $116 per year. Farm 26 had $357 greater cost of horse labor per year compared to the average while farm 28 had $203 extra horse cost. Table 7 shows the cost per hour of horse labor on each farm each year.

Table 7.—Cost Per Hour for Horse Labor for Each Farm Each Year Studied

Farm No.	1922	1923	1924	1925	1926	1927	1928
1	$.1492	$.2378	$.2408	$.2414	$	$	$ ....
2	.2503	.1996	.2523	.2451	....	....	....
5	.1348	.1434	.1259	.1177	.1143	.1182	.1475
6	.2172	.1747	.1690	.1455	....	....	....
7	.2946	.1835	....	....	....	....	....
8	....	.2041	....	.0902	....	....	....
9	.1743	....	....	....	....	....	....
11	.1224	.1155	.1223	.2234	.1140	....	....
12	.0996	.1126	.096	.1234	.1249	....	....
13	.1922	.0965	.1454	.1160	.1029	.1050	.0837
14	.0763	.1064	.0976	....	....	....	....
15	.1208	.1292	.1187	....	....	....	....
16	.1211	.1397	....	....	....	....	....
17	.1090	.1013	.1330	.1405	.1091	....	....
18	.1466	.1578	....	....	....	....	....
20	.1452	.1007	.1280	....	....	....	....
21	.1286	.1424	....	....	....	....	....
24	.2422	.1356	....	....	....	....	....
25	.1389	.1396	.1398	.1581	.1433	....	....
26	.1562	.1681	.1711	.1807	.2060	.1971	.2703
27	.2265	.1716	.2075	.2145	.1471	.0920	....
28	.1789	.2254	.2446	.2631	.1917	.1990	.2100
29	.1820	.2119	.2282	.2104	.1775	....	....
31	....	....	.1512	.1540	.1380	....	....
32	....	....	.1400	....	....	....	....
33	....	....	.2260	.1531	.1316	.1432	....
34	....	....	.1249	.1778	.1352	.1733	....
35	....	....	....	.1940	.1574	....	....
36	....	....	....	.2350	....	....	....
38	....	....	....	.1210	.1610	.1036	.0990
39	....	....	....	.1997	.2267	....	....
40	....	....	....	.1240	.1162	.0934	.1291
42	....	....	....	....	.1765	.1123	.1720
43	....	....	....	...	.1500	....	....
45	....	....	....	....	....	.0942	....

One of the things that seems to affect the cost of horse labor is the use of a tractor. Several men included in this study purchased a tractor during the years 1924 to 1927.

In 1923 farm 17 secured 1406 hours work from each horse at a cost of 10.13 cents per hour. In 1924 the operator of this farm had a tractor. His horses in 1924 worked 1371 hours each at a cost of 13.3 cents per hour. In 1925 the horses worked 1335 hours each at a cost of 14.05 per hour. This farmer had a high standard of use of horses. The average on all farms showed 874 hours worked per horse in 1923. Farm 17 had 1406. In 1924 the average was 962.

Farm 17 had 1371. In this case the hours per horse were slightly reduced and the cost per hour slightly increased after the tractor was purchased.

Compare this with farm 26. In 1926 and 1927 farm 26 secured about 650 hours of work per horse at a cost of about 20 cents per hour. In the year 1928 the operator of this farm had a tractor. He worked his horses only 588 hours each and it cost him 27 cents per horse hour. Here was a case where the horses had not been used as much as normal. Then a tractor was purchased and the horses remained idle, running up a big feed bill while the tractor was doing the work. Any saving that this farmer might have made by using the tractor was more than lost by the heavy cost of keeping idle horses.

Farm 17 operates approximately 223 acres of land with 5 horses and a tractor. The operator of this farm plants about as many row crops proportionately as the operator of farm 26 who has 10 horses and a tractor. Farm 17 follows a cropping program that necessitates more plowing than farm 26. The operator of farm 26 has potatoes in his rotation and need not plow for beets. Therefore farm 26 does not need a tractor. In addition, this farm is overstocked with horses. The cost of horse labor each year was as follows:

Table 8.—Cost of Horse Labor by Years

Year	Number farms	Horses per farm	Hours worked per horse	Cost per hour	Cost per horse
1922	22	8.2	807	$.1438	$116.20
1923	23	8.2	874	.1338	117.02
1924	20	8.8	962	.1465	140.90
1925	22	8.4	912	.1535	140.07
1926	19	8.8	1077	.1377	148.31
1927	11	8.7	935	.1199	112.13
1928	7	9.0	857	.1355	114.92
Weighted average	123	8.7	921	$.1405	$129.39

The most important method of reducing the cost per hour of horse labor seems to be that of keeping the horses at work. Idle horses cost money. The feed that they consume can be used to a better purpose for cattle or sheep. If there is not enough work to keep them busy it is possible by a little planning to do the work with one or two less horses. The relation between hours worked per horse and costs is shown by the following comparison made for the first 6 years of the study.

Table 9.—Relation of Hours Per Horse to Horse Costs

Hours worked per horse from	to	Av. hours worked per horse	Number farms	Cost per hour	Cost per horse
0 —	500	446	16	$.1835	$ 81.78
501 —	700	612	19	.1675	102.61
701 —	900	795	23	.1364	108.44
901 —	1100	1010	23	.1228	124.04
1101 and over		1298	35	.1073	139.16

The cost of keeping a horse a year increased as he was worked harder, but not as fast in proportion. Horses in the last group worked 1298 hours each or nearly three times as much as those in the first group. The cost per horse increased about $58 or 70 percent, but the cost per hour was nearly 8 cents less or a decrease of over 41 percent.

Equipment Costs.—The equipment costs in this study have been prorated to each crop on the basis of the number of hours of horse labor spent on that crop. The average cost of equipment per hour for the period studied figured in this way was 6.22 cents. Comparing this with the cost of horse labor per hour (14.05 cents) it shows that equipment costs were about 44 percent as much as horse-labor costs.

For the year 1926 some of the most common machines were studied separately to find the costs for each machine. The averages for all farms for 1926 are shown in the following table. The outstanding thing about this is the small number of hours that any one machine was actually used. Wagons were used 342 hours each per year; beet pullers, 171 hours; plows, 155; while grain binders were used only 44 hours. Many farms had more than one machine. From 30 to 40 acres seemed to be about the limit of area for one machine. Potato diggers cost nearly $1 per acre. Harrows cost only 6 cents. Grain binders cost the most per hour used, 37.95 cents. Wagons cost the least, 6.14 cents.

These costs per hour might be used as a guide to the rental value of machinery. On the basis of a 10-hour day grain drills cost $2.80; grain binders, $3.80; and wagons, 61 cents.

The investment in machinery on these farms was between $1200 and $1400. The total annual cost of operating machinery was $431 per year per farm or over one-third as much as the value of machinery.

Table 10.—The Cost and Use of Farm Machinery in 1926 on Weld County Irrigated Farms

Machine	Hours used per mach.	Acres per machine	Cost: Per hour cents	Cost: Per acre once over cents
Plow	155	38.8	11.38	45.52
Harrows	56	40.7	10.72	6.00
Grain drill	53	52.3	28.04	28.60
Potato planter	58	31.4	25.60	47.10
Sugar-beet planter	48	49.5	33.16	32.50
Sugar-beet cultivator	143	36.6	16.20	13.77
Potato cultivator	118	26.7	7.61	11.49
Mower	74	25.8	20.60	19.98
Rake	25	14.6	34.69	20.12
Binder	44	43.4	37.95	58.06
Potato digger	91	31.5	33.87	98.22
Sugar-beet puller	171	40.5	11.02	46.61
Wagons { 167 on crop / 175 on stock }	342 total		6.14	

Threshing Costs.—Custom rates for threshing varied in the area according to the amount of help furnished with the threshing crew. Where the farmer did his own hauling of grain to the thresher the most common charge was 6 cents per bushel on barley and oats, and 8 cents on wheat. Where the hauling was done by the threshing crew the customary rate was 10 cents per bushel on barley and oats, and 12 cents on wheat.

A small cooperative threshing machine.

A 5-year average on two farms that were part owners of a neighborhood thresher showed that it cost them 10 cents per 100 pounds to thresh all grain. This includes interest and depreciation

on the investment in the threshing rig. With usual weights per bushel that are common for machine measure, namely, 40 pounds for oats, 50 for barley, and 60 for wheat, this gives a cost of 4 cents per bushel of oats, 5 cents per bushel of barley and 6 cents per bushel of wheat. These costs are somewhat less than custom rates where farmers do their own hauling. However, no charge for the men operating the rig is included in this charge. The wages of two men per day for tending the machine would raise these rates, so that there would be very little real saving other than the convenience of threshing when ready.

Tractor Costs.—Tractor operation and charges were kept separate from farm machinery. Twenty-two records scattered thru the years showed that each tractor was used an average of 267 hours per year at a cost of practically $1 per hour. This includes cash costs, depreciation and interest. In 1924 three men used their tractors 353 hours each at a cost of 69 cents per hour. In 1927 two men used their tractors 181 hours each at a cost of $2.50 per hour. Depreciation and interest count up fast on an idle tractor, just as the feed bill counts up on an idle horse.

Irrigation or Water Tax.—The charge for the use of irrigation water was distributed on the basis of the area irrigated once. If potatoes or beets were irrigated five times, they received five times as large a charge per acre as did barley that was irrigated once. Early and late water were not separated in making this charge, as it was practically impossible to keep reservoir and river water charges separate, often with both kinds of water coming thru the ditch at the same time. Consequently the water charges shown on these farms are somewhat less for late crops such as potatoes and beets, than would be the case if they stood the entire cost of reservoir water. The total cost of water per farm was highest in 1925, amounting to $339, and lowest in 1923, being only $187. This coincides with the weather records which show 1923 to be the wettest and 1925 the driest year included in the study. In 1926, which was considered by many to be about ideal for crop growth, the irrigation cost per farm was $311, or 57 cents per acre for one irrigation.

Building Charge.—The use of buildings was distributed on the basis of the value of buildings used by each class of livestock or crop. The residence furnished to beet workers was charged to sugar beets; potato cellars to potatoes, etc. The total annual cost of buildings per farm was usually between $300 and $500. Individual farms varied from this figure due to size of farm or amount of buildings. On the whole these farms were well equipped with buildings.

Overhead Costs.—In checking over the records on these farms

every effort was made to charge labor and expenses directly to the part of the farm business that used them. But there were some items that could not be disposed of that way, or if they were, they resulted in a charge to an unproductive part of the farm business. Labor was used repairing fences, making roadways, or cleaning along ditches and fences; cash was spent for telephone and electric light charges, association dues and items for general farm repair; the auto or truck was used for general farm work. These and similar items represent what is called overhead.

These overhead charges have been distributed to the crops and livestock on the basis of the hours of man labor used by the different enterprises. This method was used because of the ease of checking, because man labor was involved to a large extent in the charges themselves, and because it is one of the methods used for distributing such charges in industry. Any method of distributing overhead is arbitrary and open to some criticism; consequently the effort was made to select a base that could be used by any farmer wishing to compare his own farm with the average shown in this study.

The average overhead per farm and per hour spent on productive enterprises is shown in the following table:

Table 11.—Overhead Charge Per Farm and Per Man Hour

Year	Total overhead charged	Overhead charged per man hour
1922	$386.67	$.0820
1923	434.12	.0822
1924	500.40	.0842
1925	541.75	.0955
1926	718.36	.1074
1927	632.42	.1209
1928	732.28	.1364

At the outset it was thought that the amount of overhead would decrease as the study progressed. Actually it increased. The reason apparently was that more and more detail was secured as the men became familiar with the work, consequently the items of general farm expense were more accurately reported the last years than at first. Also more trucks and autos were used for general use as the years went past. The significant thing is that these overhead items amounted to about one-third as much as the regular labor cost on these farms.

Manure Charge.—The charge for the use of manure was distributed to each crop on the basis of the amount of fertility removed. The value of man and horse labor spreading manure, the use of the manure spreader, and the value of the manure, usually estimated

as $1 per ton, all were added to find the total manure charge for each farm.

The yield of each crop was reduced to tons. For each crop a figure was used[1] that reflected the relative amount of fertility required in its production. This was based on a table prepared by the United States Department of Agriculture showing the relative use of fertility per ton by the important crops. By this method the entire manure charge was distributed each year, and none of it was held over as a deferred charge for the following crops.

The effect of farm manure is seen in crop yields over a period of years. A farm using farm manure consistently shows an increase in crop yields over a period of years. Practically all farmers in this section rotate their crops, if not by a definite area each year, at least according to a general plan of following alfalfa by potatoes, then by sugar beets, then by grain seeded back into alfalfa. Manure is quite generally applied to the sugar beets direct or to the potatoes. Other crops coming after these crops benefit from the residue left in the soil. All the hours of labor and other costs of applying manure are distributed as stated above. This reduced the hours that farmers might show for crops where they have made direct application to some one crop. The actual time spent per acre manuring each crop is shown in Table 38 in connection with the discussion of labor by operations.

Cash Costs.—All the items of cost as used in this study were based on cash out-of-pocket cost plus calculated items. The labor of the operator and his family was charged at current rates for labor. Horse costs include home-grown feeds at their farm value, also interest on investment and a credit for manure. Depreciation and interest were figured on buildings, machinery, etc. Interest on land was shown separately in each case, but interest on horses, equipment, tractor or truck was included in the charge for these items.

A study of the results will show many cases where crops were produced at a loss, yet farmers continued to grow the crop. There are several reasons why they do not abandon crops under such circumstances. They may hope for better yields or prices next year. They may know the reason for loss and plan to avoid it next year. It may be due to weather conditions that are abnormal. But in addition to these there is the point which some believe is most important of all, namely, that farmers consider cash out-of-pocket costs when they decide whether to keep producing or to quit. Cash costs are not the total. Depreciation must be met if the farmer is

[1]For potatoes, sugar beets and root crops this figure was 1; for alfalfa hay, peas and beans it was 2; and for field corn and small grains it was 6.

to remain in business. He must get paid for his own time if he plans to meet his grocery bills. He should allow for interest on his investment before he decides that a crop is profitable.

Just what is the relationship between total costs and actual cash out-of-pocket expenses? In an endeavor to answer this question the records for the year 1926 were analyzed in detail. This year was selected as coming nearest to a normal year. Results based on this year might be used as a guide in noting the relationship that should exist. Abnormal conditions largely speak for themselves.

For the year 1926 the percentage of each item of cost that was cash out-of-pocket expense is shown in the following table as an average for all farms that year. Taxes and irrigation water are all cash.

Table 12.—Relation of Cash to All Expenses for 1926

Item	Cash as a percentage of total cost pct.
Taxes	100.0
Irrigation water	100.0
Overhead	51.4
Truck	44.9
Equipment	43.4
Tractor	43.2
Man labor	42.3
Horse labor	19.8
Building charge	19.3
Manure	12.2

Overhead is the only other item for which cash is over 50 percent of the total expense. With man labor cash was 42.3 percent of the total expense. With horse labor it was only 19.8 percent.

By applying these detailed percentages to each item of expense, the cash cost of producing each crop in 1926 in relation to total costs was as follows:

Table 13.—Proportion of Crop Costs That Were Cash in 1926

Crop	Cash costs as a percentage of— Operating cost pct.	Total cost pct.
Alfalfa	50.4	31.9
Barley	54.6	37.1
Wheat	55.8	37.3
Oats	56.2	37.3
Sugar beets	63.4	53.5
Potatoes	42.7	36.7
Beans	56.9	41.6
Corn for grain	43.6	33.6

Sixty-three and four-tenths percent of the operating costs on sugar beets was cash. Only 42.7 percent of the operating costs on

potatoes was cash. The lower percentage shown for total costs is on the assumption that interest on the investment in land shown as a cost is all computed. As a matter of fact most farmers pay interest on mortgages. A correction for this should be made in the case of a farmer in debt. The actual cash and non-cash items of cost for each crop for the year 1926 were as follows:

Table 14.—Cash and Non-cash Costs Per Acre 1926

Crop	Operating costs		Non-cash interest on land	Value of crops per acre
	Cash	Non-cash		
Alfalfa	$10.64	$10.44	$12.23	$20.53
Barley	14.12	11.70	12.20	25.45
Wheat	17.39	13.70	15.45	48.35
Oats	14.11	10.95	12.76	33.36
Sugar beets	51.36	31.22	13.42	148.08
Potatoes	36.88	49.46	14.11	136.78
Beans	21.99	16.66	14.26	46.90
Corn grain	16.13	20.88	10.75	39.60

When one considers the first column of cash operating costs it is apparent that a farmer must have secured rather poor yields or low prices before his income per acre fell below the cash cost per acre. The value per acre of each crop for 1926 is shown in the last column. Not a crop in the list but shows a good balance above actual cash expenses. This was a year of good yields and fair prices.

Instead of laying too much emphasis upon these cash items, farmers would do well to consider the total of cash and non-cash before deciding as to the profitableness of any one crop.

Cost of Producing Crops

Costs were worked out on all crops grown on these farms. Some crops were grown on all farms, some on a majority of the farms, while scattered crops were grown on only one or two farms. The important crops for this region were alfalfa, potatoes, sugar beets, barley, wheat, oats and beans. Crops that were grown to a much less extent were corn for grain, silage corn, pastured corn, cabbage, peas, sudan and cane, onions and popcorn. The results on these minor crops are far from conclusive. Especially is this true for grain corn. In practically no instance was grain corn grown as a major important crop on these farms. It was usually planted as a filler and given scant consideration.

At the other extreme, sugar beets on these farms received first place in attention and care. The soil was adapted to methods which reduced the time required per acre for handling sugar beets, and the general care given the crop resulted in average yields considerably in excess of the averages for Northern Colorado.

In the case of the important crops, the number of farms reporting the crop varied so from year to year that it seemed best to show the average of all years as an average of each yearly figure. In all cases the acre costs are based upon the harvested acreage. Some years a large acreage of failure causes the cost per acre that year to be excessive, yet it represents the risks for that particular crop.

The total cost of labor is shown in the tables for each crop. For the time spent on each operation see Table 38.

Potatoes.—Table 15 gives the area, production, hours of labor and costs per acre for potatoes on farms where records are available for 4 or more years. Farms 12 and 13 had the lowest costs per acre for the period studied. Farms 25 and 11 had the highest yields. Both these farms are favored with level, productive land, kept in high fertility by frequent applications of manure.

Planting potatoes on well-prepared alfalfa ground.

The higher yields of potatoes secured on farms 11 and 25 were mainly due to more care in seed selection, adherence to a more strict rotation, and character of soil. The soil on these two farms was of a more sandy nature than that on many of the other farms. Disease was not so prevalent on these two farms, mainly due to the fact that potatoes very seldom were planted after potatoes, but followed alfalfa or a cultivated crop such as beans; the ground planted to beans having been out of potatoes at least 3 years.

Farm 12 secured a relatively cheap cost as a result of the use of labor on the crop. All necessary work was performed at the

proper time, climatic conditions permitting. All unnecessary work was eliminated. Crop rotation was adhered to as a general policy, modified according to the farmer's judgment. Potatoes might follow potatoes 2 years in succession if the price outlook was favorable.

Table 15.—Summary of Potato Production on Farms with 4 or More Years Record

Farm No.	Number years	Area harvested	Yield per acre	Yield accounted for	Hours per acre		Per acre costs	
					Man	Horse	Operating	Total
			Lbs.	Lbs.				
5	6	32.53	11,959	10,469	58.55	85.06	$75.42	$92.57
11	5	26.40	12,888	9,889	58.01	75.32	73.85	94.24
12	5	80.34	12,091	9,933	45.25	83.56	67.05	78.86
13	6	58.53	9,049	6,860	36.10	66.05[1]	67.85	82.31
25	5	20.27	15,622	13,000	65.20	98.07	83.41	97.12
26	6	23.94	11,136	8,463	72.50	88.40	81.68	98.72
28	6	20.12	9,927	7,828	63.00	67.70	77.30	94.34
29	5	24.79	11,165	9,542	61.00	66.50	90.87	107.95

[1]This farm also had an average of 2.67 hours tractor labor per acre.

Farm 13 reduced the labor requirements on potatoes by the purchase of a power sorter. In addition, a tractor was used for plowing and a truck for marketing the potatoes, which aided in reducing the hours per acre required for the crop. Farm 13 showed the lowest average yield per acre of all farms. The yields on this farm

Harvesting potatoes in Greeley area.

varied from 12,000 pounds to 4,875 pounds per acre, the latter occurring in 1926 when germination was poor and growth stunted even tho the soil preparation had been excellent. The fear of a repetition of another dry year such as 1925 resulted in irrigating potatoes before planting, and this apparently caused the seed to rot and resulted in a poor yield.

The average results each year in producing potatoes are shown in Table 16. The number of farms growing potatoes varied from 21 in 1922 to 8 in 1927. For the year 1928 the final sales in the spring of 1929 were not completed in time to include the results in this study. In all 89 records are available. The average for the 6 years shows what could be expected on a farm that grew potatoes each year under the conditions that were found in this study.

Table 16.—Average Yearly Cost Per Acre of Producing Potatoes, 1922 to 1927

	1922	1923	1924	1925	1926	1927	Yearly average
Number of farms	21	20	14	13	13	8	....
Acres in crop harvested	31.09	26.61	26.66	31.37	31.43	26.27	28.91
Yield per acre, lbs.	10,311	11,774	13,071	11,619	9,868	12,120	11.461
Accounted for per acre	7,826	9,235	11,445	9,528	8,443	9,370	9,308
Waste per acre, lbs.	2,485	2,539	1,626	2,091	1,425	2,750	2,153
Seed per acre, lbs.	788	842	816	830	864	894	839
Man hours per acre	50.79	53.21	49.31	57.20	53.20	56.95	53.44
Horse hours per acre	82.16	81.44	82.09	79.40	76.95	84.57	81.10
Tractor hours per acre	.50	.50	.62	.43	.52	.22	.46
Costs per acre:							
Man labor	$17.14	$17.42	$16.69	$20.11	$18.15	$17.87	$17.89
Horse labor	12.00	11.24	12.20	11.70	10.78	9.94	11.31
Hand contract	5.02	7.20	8.38	9.00	7.21	8.00	7.47
Haul contract	.36	.58	.56	1.39	.48	.12	.58
Seed	8.17	6.27	8.83	7.16	22.64	16.28	11.56
Manure	2.62	2.02	3.42	5.05	3.07	2.92	3.18
Twine	.11	.20	.20	.25	.17	.29	.20
Sacks	3.33	5.16	6.47	7.05	5.62	5.70	5.56
Water tax	3.18	2.11	2.71	5.87	3.28	2.20	3.22
Real estate tax	3.27	3.07	2.80	2.73	2.74	3.07	2.95
Buildings	1.21	1.66	1.55	1.32	1.16	1.21	1.35
Equipment	4.05	3.39	3.79	3.66	3.79	5.96	4.11
Tractor	.90	.44	.35	.31	.38	.40	.46
Miscellaneous	.05	.48	.12	.25	.38	1.95	.54
Overhead	3.41	4.33	4.15	5.05	6.49	6.80	5.04
Total operating cost	$64.82	$65.57	$72.22	$80.90	$86.34	$82.71	$75.42
Interest on land	16.66	15.23	14.49	15.16	14.11	13.35	14.84
Total all costs	81.48	80.80	86.71	96.06	100.45	96.06	90.26
Value per cwt.	.389	.795	.75	2.29	1.62	.84	1.114
Value per acre	30.44	73.42	85.84	218.19	136.78	78.71	103.89
Returns per acre:							
Without interest	—34.38	7.85	13.62	137.29	50.44	—4.00	28.47
With interest	—51.04	—7.38	—.87	122.13	36.33	—17.35	13.63
Cost per cwt. used:							
Without interest	.84	.71	.63	.85	1.02	.88	.81
With interest	1.04	.88	.76	1.01	1.19	1.02	.97

Such a farm would have 28.91 acres of potatoes yielding 11,461 pounds or about 100 sacks at harvest time. Of this production 9,308 pounds were accounted for during the year either by sales, home use, seed or feed. The balance of 2,153 pounds or 18.8 percent of the total harvested was lost by shrinkage or thrown out at sorting time. This item of waste was heavy on some farms, amounting to

as high as 4,000 to 8,000 pounds in several instances, due to freezing, rot or other disease. In 1926 the least shrinkage occurred, and in 1927 the largest shrinkage. The years 1922 and 1923 were also years of heavy shrinkage. In the fall of 1925 a heavy freeze caused severe losses on some farms.

Table 17.—Cost Per Acre of Producing Potatoes, 1922 to 1927. Farms With Low Costs Per 100 Pounds Each Year

	1922	1923	1924	1925	1926	1927	Yearly average
Farm No.	24	25	6	25	25	38	....
Acres in crop harvested	44.49	19.34	15.53	17.39	20.45	43.20	26.73
Yield per acre, lbs.	13,756	15,512	19,349	17,369	17,070	16,667	16,620
Used per acre, lbs.	10,790	15,032	18,403	15,012	14,636	14,533	14,734
Waste per acre, lbs.	2,966	480	946	2,357	2,434	2,134	1,886
Man hours per acre	42.50	64.94	66.06	78.75	65.28	62.99	63.42
Horse hours per acre	63.25	105.33	89.25	90.10	108.00	70.83	87.79
Tractor hours per acre	1.10	....	....	....	....	....	.18
Cost per acre:							
Man labor	$18.68	$22.47	$23.07	$27.87	$24.87	$22.55	$23.25
Horse labor	15.30	14.73	15.08	14.23	15.45	7.36	13.69
Hand contract	6.68	8.73	12.31	10.66	9.05	10.25	9.61
Haul contract	.45	....	1.25	....	....	....	.29
Seed	6.50	4.39	6.40	7.18	28.20	16.22	11.48
Manure	....	3.87	....	9.16	4.08	6.12	3.87
Twine	.20	.83	.45	.29	.38	.14	.38
Sacks	3.12	4.52	14.65	4.48	8.98	8.02	7.29
Water tax	3.07	1.23	1.65	6.27	1.47	.63	2.39
Real estate tax	2.22	3.47	2.34	3.21	3.58	3.31	3.02
Buildings	.21	.80	....	.17	.32	.53	.34
Equipment	4.53	4.24	3.01	3.80	3.77	5.74	4.18
Tractor	2.84	....	....	....	....	....	.48
Miscellaneous	.22	....	....	.07	....	3.97	.71
Overhead	1.84	6.54	6.06	9.41	9.67	9.48	7.17
Total operating cost	65.86	75.82	86.27	96.80	109.82	94.32	88.15
Interest on land	18.37	14.13	16.23	13.50	12.58	11.28	14.35
Total all costs	84.23	89.95	102.50	110.30	122.40	105.60	102.50
Value per cwt.	.525	.764	.75	2.48	1.55	.84	1.17
Value per acre	56.65	114.84	138.02	372.30	226.86	122.08	171.79
Returns per acre:							
Without interest	—9.21	39.02	51.75	275.50	117.04	27.76	83.64
With interest	—27.58	24.89	35.52	262.00	104.46	16.48	69.29
Cost per cwt. used:							
Without interest	.61	.504	.47	.64	.75	.65	.60
With interest	.78	.598	.56	.73	.84	.73	.70

Table 18.—Cost Per Acre of Producing Potatoes, 1922 to 1927.
Farms with High Costs Per 100 Pounds Each Year

	1922	1923	1924	1925	1926	1927	Yearly average
Farm No.	18	14	26	26	26	28	....
Acres in crop harvested	22.21	29.00	22.48	24.54	56.77	20.37	29.23
Yield per acre, lbs.	7,866	4,966	9,175	11,808	4,822	2,946	6,930
Used per acre, lbs.	2,199	4,547	6,289	7,591	3,415	1,267	4,218
Waste per acre, lbs.	5,667	419	2,886	4,217	1,407	1,679	2,712
Man hours per acre	32.92	61.52	56.90	89.17	36.48	34.81	51.97
Horse hours per acre	69.52	104.28	69.48	107.38	65.02	56.04	78.62
Cost per acre:							
Man labor	$ 9.52	$21.59	$14.85	$28.18	$13.79	$12.91	$16.81
Horse labor	10.22	11.05	11.88	19.43	6.70	11.15	11.74
Hand contract	4.18	....	....	11.62	4.25	6.13	4.36
Haul contract	....	....	....	.13	.83	....	.16
Seed	7.87	7.92	11.37	7.21	25.03	12.75	12.02
Manure	1.94	.66	5.57	6.94	.94	....	2.68
Twine	....	.21	....	.30	.10	.15	.13
Sacks	....	3.20	8.34	6.78	3.33	1.32	3.83
Water tax	3.03	.69	1.13	4.94	2.79	.39	2.16
Real estate tax	4.29	3.06	3.02	2.67	2.67	2.55	3.04
Buildings	....	5.45	.35	.18	2.65	1.20	1.64
Equipment	3.38	5.56	2.63	4.92	2.54	3.21	3.71
Miscellaneous	....	.17	.01	....	2.48	1.19	.64
Overhead	4.75	8.11	4.33	6.63	4.21	4.68	5.45
Total operating cost	49.18	67.67	63.48	99.93	72.31	57.63	68.37
Interest on land	20.94	18.06	17.35	17.34	12.94	13.60	16.70
Total all costs	70.12	85.73	80.83	117.27	85.25	71.23	85.07
Value per cwt.	.188	.687	.70	2.10	1.62	.73	1.20
Value per acre	4.13	31.24	44.02	159.41	55.32	9.25	50.56
Returns per acre:							
Without interest	—45.05	—36.43	—19.46	59.48	—16.99	—48.38	—17.81
With interest	—65.99	—54.49	—36.81	42.14	—29.93	—61.98	—34.51
Cost per cwt. used:							
Without interest	2.24	1.49	1.01	1.32	2.11	4.55	1.62
With interest	3.19	1.89	1.28	1.55	2.50	5.62	2.02

It took 43.44 man hours, 81.1 horse hours and 0.46 tractor hours per acre to produce, harvest, sort and sell an acre of potatoes. This does not include contract picking of the potatoes.

Seed cost an average of $11.56 per acre for 839 pounds. Sacks cost $5.56; water, $3.22; equipment, $4.74; overhead, $5.04; operating costs were $76.05 per acre; total costs, $90.26. The value of the crop was $103.89 per acre, giving a profit for the 6 years above all costs of $13.63.

The cost of producing 100 pounds of potatoes accounted for was 81 cents without interest, and 97 cents with interest. The average sale price was $1.11 per 100 pounds.

There were many variations from farm to farm and from year to year. Yields per acre varied from as low as 2,946 pounds to 19,804 pounds per acre. Farmers showed ability in some cases to cut their costs and in other cases they had high costs. For each year the

farm was selected which had the lowest total cost per 100 pounds accounted for, and the farm with the highest cost. Tables 17 and 18 show these farms and the 6-year average in each case.

The six low-cost farms showed an average yield per acre of 16,620 pounds, of which 14,734 were accounted for, while the six high-cost farms, had yields of only 6,930 pounds per acre, of which only 4,218 pounds were accounted for. Obviously yield per acre was the big factor that caused these men to have low or high costs per hundredweight produced. It cost the first group $20 per acre more to produce potatoes, but they made a profit of $69.29 per acre where the second group lost $34.51 per acre.

The price at which farmers sold their potatoes showed more variation than might be expected. In 1922 six men got over 50 cents per 100 and four men got less than 25 cents per 100 pounds.

In 1923 four men got over 90 cents per 100 pounds and three got less than 65 cents. In 1924 two men got over 85 cents per 100 pounds and three got less than 65 cents. In 1925 two men got more than $2.90 and four got less than $2.15 per 100 pounds.

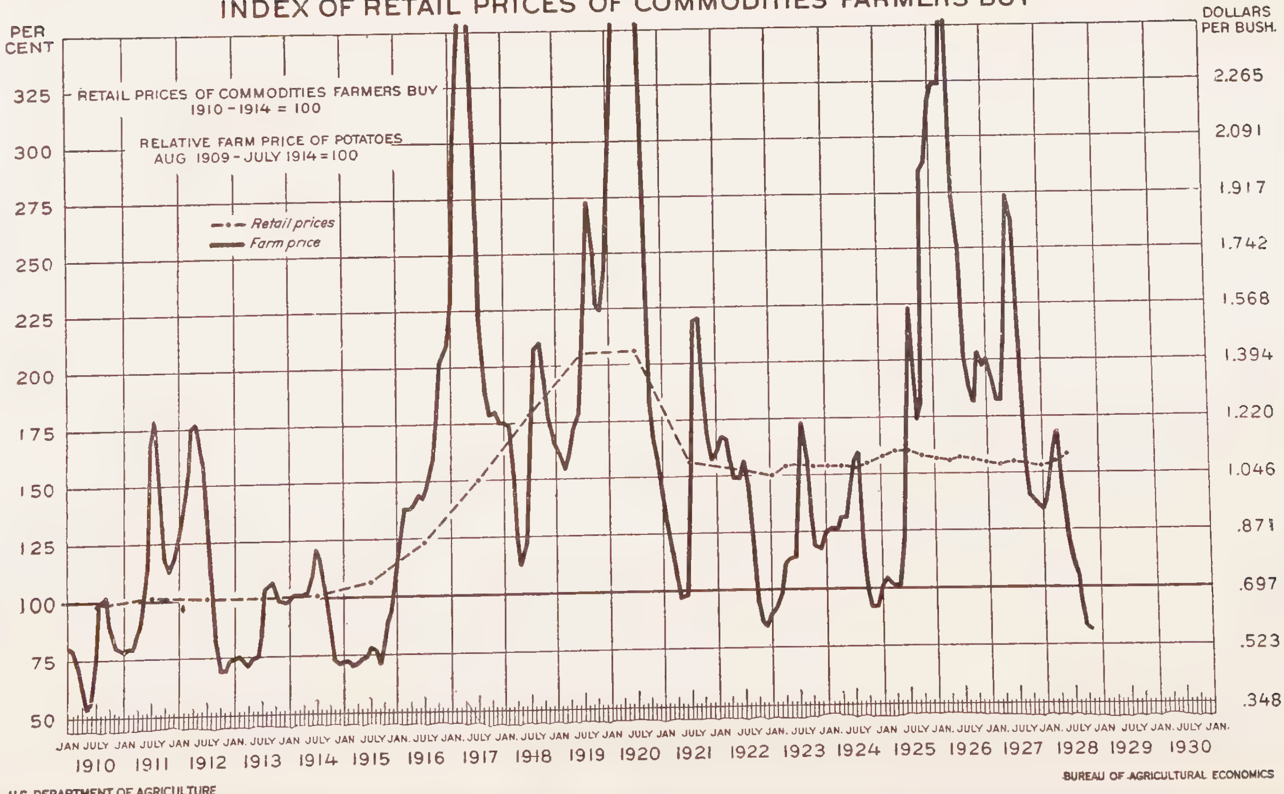
Obviously with a crop like potatoes where there are wide fluctuations in market price, the final results of the year's work depend nearly as much upon the ability to make a good sale as they do upon the ability to grow a large crop at a low cost. Yet in the long run the farmer who can produce a high yield at a low cost will win because the wide fluctuations in potato prices are between years. The accompanying chart shows how the price paid to farmers in the United States has varied from year to year.

The most consistent farms in producing potatoes for a low cost were farms 12 and 25. Records are available for each of these farms for the 5 years, 1922 to 1926 inclusive. They show as follows:

Table 19.—Five-year Average Potato Record on Two Farms

Item	Farm 25	Farm 12	Av. of 93 records
Average potato area	20.27	80.34	28.89
Yield per acre, lbs.	15,622	12,091	11,363
Pounds accounted for	13,000	9,933	8,744
Waste, lbs.	2,622	2,158	2,017
Man hours per acre	65.2	45.25	53.07
Horse hours per acre	98.07	83.56	80.98
Operating cost per acre	$83.41	$67.05	$73.53
Total cost per acre	91.12	78.86	88.88
Operating cost per cwt. accounted for	.641	.675	.841
Total cost per cwt	.747	.794	1.016

FARM PRICES OF POTATOES
AND
INDEX OF RETAIL PRICES OF COMMODITIES FARMERS BUY



The significant thing is that these two farms required sale prices of at least 75 cents per 100 pounds to pay all costs, while for all records all years a price of $1 per 100 pounds was necessary. Analysis of 81 records for 5 years showed the following:

Table 20.—Effect of Net Yield and Price Upon Profit from Potatoes

Pounds per acre accounted for: from	to	Number farms	Number making a profit	Number having cost over $1 per cwt.
0	8,000	27	3	27
8,001	10,000	26	8	13
10,001	12,000	16	7	1
12,000 plus		12	10	0
Price received for potato sales per cwt.: from	**to**	**Number farms**	**Number making a profit**	
0	75c	42	0	
76c	$1.00	13	7	
$1.00 and above		26	22	

Ten farms out of the 12 with yields over 12,000 pounds per acre made money and none of them produced potatoes at a cost as high as $1 per 100 pounds.

Twenty-two farms out of 26 that sold potatoes for $1 per 100 pounds or above made money.

Look at it either way and one comes to the same conclusion, that yields of 12,000 pounds or better, or prices of $1 per 100 pounds or better, are needed in order to make money with potatoes.

Sugar Beets.—The average cost per acre of producing sugar beets is shown for each year in Table 21. Average yields each year varied from 11.25 tons in 1922 to 18.51 in 1926. The year 1925 was a hard year for sugar beets to get started. The area that grew and was harvested that year made fairly good yields.

The yearly average for 6 years shows 14.92 tons per acre. This is somewhat less than an average based on total area harvested in the 6 years. This shows 15.77 tons per acre, due to the fact that more records were secured in years with high yields.

The contract labor shown is based on actual payments divided by measured area harvested. This does not agree exactly with the standard payments per acre which are based on areas computed by field men of the sugar company.

The section of Weld County in which these farms are located has certain advantages for sugar-beet production which result in higher yields than can be secured elsewhere for the same cost.

The chief advantage possessed by the area in Northern Colorado in the raising of sugar beets is that of climate. The monthly

mean temperature at Fort Collins over a period of 40 years is 46.5 degrees, while that of Rocky Ford is 52 degrees. Yields of sugar beets in these respective sections were 15.57 tons and 12.99 tons.[1]

Table 21.—Average Yearly Cost Per Acre of Producing Sugar Beets, 1922 to 1927, Inclusive

	1922	1923	1924	1925	1926	1927	Yearly average
Number of farms	12	13	17	10	17	10	....
Acres in crop harvested	23.31	26.63	37.17	20.19	43.87	43.97	36.08
Yield per acre, tons	11.25	15.38	16.02	13.68	18.51	14.68	14.92
Seed per acre	16.5	16.2	16.8	43.	18.	22.6	22.2
Man hours per acre	35.35	36.20	37.88	59.20	40.22	35.30	40.69
Horse hours per acre	72.00	81.82	77.76	113.56	81.30	77.50	83.99
Tractor hours per acre	....	.38	.50	2.35	.56	.47	.71
Costs per acre:							
Man labor	$11.60	$11.58	$12.97	$18.42	$13.22	$10.30	$13.01
Horse labor	9.51	9.93	11.20	16.35	11.02	9.21	11.20
Hand contract	17.15	21.17	23.72	19.37	26.33	24.66	22.07
Haul contract	....	.82	.05	.41	1.46	.38	.52
Seed	3,12	2.43	2.52	6.50	2.75	3.37	3.45
Manure	5.48	5.04	7.48	13.41	9.59	6.62	7.94
Water tax	2.20	1.43	2.18	4.62	2.77	2.32	2.59
Real estate tax	3.41	3.20	3.02	2.62	2.94	3.20	3.06
Buildings	.43	.60	.57	1.75	.49	.40	.71
Equipment	3.09	3.44	3.85	6.32	4.71	5.31	4.45
Tractor	....	.28	.37	1.74	.57	1.28	.71
Truck	....	.20	.13	.22	1.83	1.71	.68
Miscellaneous	.18	.07	1.15	.31	.75	.31	.46
Overhead	2.46	2.96	3.15	4.28	4.15	4.37	3.56
Total operating cost	58.63	63.15	72.36	96.32	82.58	73.44	74.41
Interest on land	14.78	14.71	14.04	13.05	13.42	12.90	13.82
Total all costs	73.41	77.86	86.40	109.37	96.00	86.34	88.23
Value per ton	7.88	8.19	7.50	6.00	8.00	8.00	7.62
Value per acre	88.65	125.96	120.15	82.08	148.08	117.44	113.73
Returns per acre:							
Without interest	30.02	62.81	47.79	—14.24	65.50	44.00	39.32
With interest	15.24	48.10	33.75	—27.29	52.08	31.10	25.50
Costs per ton:							
Without interest	5.21	4.10	4.52	7.04	4.46	5.00	4.99
With interest	6.52	5.06	5.39	7.99	5.18	5.88	5.91

Sugar beets are a relatively cool-climate crop. The temperature during the months of June, July and August is very important. A comparison of temperatures during these months at Rocky Ford and Fort Collins is given below:

	June	July	August
Fort Collins	63.4	68.3	67.3
Rocky Ford	70.5	74.8	73.4

Not only is the temperature during these months important, but the temperature between night and day just preceding beet harvest is also an important factor in the development and the storage of sugar. The maximum activity of sugar storage is during

[1]U. S. D. A. Bul. 917, Farm practice in growing sugar beets in three districts of Colorado.

Using furrow openers on a beet drill permits early cultivation or irrigation.

the last month of the growing season. Northern Colorado has cooler nights than the Arkansas Valley, and fairly warm days.

The soil in this area is medium to light. Potatoes are widely grown. Many farmers follow potatoes by sugar beets. This tends to cheapen the cost of production inasmuch as plowing is eliminated. It secures an early preparation of seedbed and allows for early planting. These are important factors in raising beets, as labor performed and yields are two important factors in cheapening costs and thereby raising the profit from sugar beets.

Many farmers feed either sheep or cattle and have sufficient manure to maintain their soil in high fertility. There is normally sufficient irrigation water to keep crops growing thru the year. These and other items have combined to make the Windsor-Eaton-Greeley area highly productive. In 1926 the farms included in this study averaged 18.51 tons of beets per acre. Northern Colorado made an average of 14.40 tons the same year. The lowest yield on any of these farms that year was 14.99 tons.

For the above reasons the average cost per acre or per ton shown for this study is less, proportionately, than what might be considered normal under Northern Colorado irrigated conditions.

Not all these farms made money on beets. Tables 22 and 23 show for each year the farms that produced beets at the lowest cost per ton and at the highest. The average for the six farms with lowest costs per ton shows a yield of 18.39 tons. The lowest yield any year was 14.02 tons in 1922. The average cost per acre, including interest, was $81.21, the cost per ton, $4.42. These men made $58.97 profit per acre.

Early cultivation of beets reduces weed growth and increases yield.

The six men with highest costs per ton had yields of 10.31 tons per acre, the highest attained by these farms was 14.99 tons in 1926. Their costs per acre were $121, and $11.74 per ton. They lost $43.31 per acre. The bad year of 1925 hit this group and partly accounted for the extremely bad showing.

In 1925 the harvested area bore the expenses of the entire sugar-beet crop. Time and money spent on abandoned beet land helped to swell the total cost. For the 6-year average this is spread over the years and represents the cost of risk of loss from the crop.

Ditching beets with a beet cultivator.

Table 22.—Cost Per Acre of Producing Sugar Beets, 1922 to 1927, Inclusive. Farms with Low Costs Per Ton

	1922	1923	1924	1925	1926	1927	Yearly average
Farm No.	17	12	25	17	38	5	....
Acres in crop harvested	16.46	49.81	20.31	51.99	36.08	35.84	35.08
Yield per acre, tons	14.02	16.23	22.15	16.18	22.28	19.52	18.39
Man hours per acre	38.70	23.33	37.86	50.38	45.87	32.17	38.05
Horse hours per acre	78.68	59.28	110.34	62.34	63.33	62.72	72.78
Tractor hours per acre	....	....	....	4.08	....	....	.68
Cost per acre:							
Man labor	$12.18	$ 7.47	$11.58	$17.83	$15.82	$ 9.91	$12.46
Horse labor	8.58	6.75	15.46	8.76	10.20	7.40	9.52
Hand contract	18.01	20.60	26.83	23.95	29.54	27.23	24.36
Haul contract	....	1.49	....	....	....	....	.25
Seed	4.45	2.04	2.99	2.62	2.61	2.61	2.89
Manure	....	3.55	9.42	8.75	3.58	5.12	5.07
Water tax	4.40	1.33	2.07	4.51	1.09	3.52	2.82
Real estate tax	2.91	2.20	3.22	2.10	2.78	3.41	2.77
Buildings	.21	.34	.69	.06	2.83	.67	.80
Equipment	3.37	1.28	4.22	4.02	3.45	4.34	3.45
Tractor	....	....	....	2.75	.03	....	.46
Truck	....	....	....	.59	5.08	3.94	1.60
Miscellaneous	.06	.10	1.51	.41	.44	....	.42
Overhead	3.16	1.35	5.01	2.81	3.94	1.85	3.02
Total operating cost	57.33	48.50	83.00	79.16	81.39	70.00	69.89
Interest on land	7.29	11.70	13.93	6.62	11.43	16.95	11.32
Total all costs	64.62	60.20	96.93	85.78	92.82	86.95	81.21
Value per ton	7.88	8.19	7.50	6.00	8.00	8.00	7.62
Value per acre	110.48	132.92	166.20	97.08	178.24	156.16	140.18
Returns per acre:							
Without interest	53.15	84.42	83.20	17.92	96.85	86.16	70.29
With interest	45.86	72.72	69.27	11.30	85.42	69.21	58.97
Costs per ton:							
Without interest	4.09	2.99	3.75	4.89	3.65	3.59	3.80
With interest	4.61	3.71	4.37	5.30	4.16	4.45	4.42

An interesting fact in connection with the cost of beets on the low-cost farms during the period of 1922 to 1927 is how the costs per ton (without interest) have varied. Inputs of materials and labor are responsible for this variation.

Farm 12 in 1923 used very few man and horse hours per acre. The general practice on this farm has been to follow some cultivated crop such as beans or potatoes with beets. Spring-toothing, harrowing and leveling are the only operations before planting beets. Timeliness of operations during the cultivating seasons reduces the number of cultivations by at least one. The distance to the beet dump does not exceed 1¼ miles from any part of the farm. Generally four-horse teams are used in hauling beets after the season is well started. This utilizes man labor to a greater degree than two-horse teams.

Table 23.—Cost Per Acre of Producing Sugar Beets, 1922 to 1927, Inclusive. Farms with High Costs Per Ton

	1922	1923	1924	1925	1926	1927	Yearly average
Farm No.	16	27	26	38	39	42	....
Acres in crop harvested	20.42	7.13	34.30	3.00	38.68	16.52	20.01
Yield per acre, tons	5.6	6.81	11.77	11.72	14.99	10.96	10.31
Man hours per acre	32.62	60.17	36.41	202.67	36.34	37.65	67.64
Horse hours per acre	84.72	75.74	78.69	360.67	63.88	91.77	125.91
Cost per acre:							
Man labor	$11.48	$14.85	$ 9.50	$78.39	$11.70	$ 8.77	$22.45
Horse labor	10.25	13.05	13.46	43.64	14.48	10.28	17.53
Hand contract	18.54	17.18	22.81	15.34	27.44	29.54	21.81
Haul contract	....	....	....	....	.55	....	.09
Seed	3.88	3.04	2.81	29.95	2.57	2.25	7.42
Manure	5.72	2.02	14.31	10.06	5.42	2.13	6.61
Water tax	3.13	.68	1.12	2.23	3.76	2.33	2.21
Real estate tax	3.42	2.66	3.02	8.49	2.22	3.40	3.87
Buildings	.44	.86	.75	34.57	.25	1.10	6.33
Equipment	3.39	3.54	2.98	18.03	5.84	5.81	6.59
Truck	....	....	....	3.99	6.68	....	1.77
Miscellaneous	....	....	.30	....	....	....	.05
Overhead	1.00	4.99	2.77	15.54	4.59	6.87	5.96
Total operating cost	61.25	62.87	73.83	260.23	85.50	72.48	102.69
Interest on land	18.85	8.43	17.51	41.57	12.07	11.43	18.31
Total all costs	80.10	71.30	91.34	301.80	97.57	83.91	121.00
Value per ton	7.88	8.19	7.50	6.00	8.00	8.00	7.54
Value per acre	44.13	55.77	88.35	70.32	119.92	87.68	77.69
Returns per acre:							
Without interest	—17.12	—7.10	14.52	—189.91	34.42	15.20	—25.00
With interest	—35.97	—15.53	—2.99	—231.48	22.35	3.77	—43.31
Costs per ton:							
Without interest	10.94	9.23	6.27	22.20	5.70	6.61	9.96
With interest	14.30	10.47	7.76	25.75	6.51	7.66	11.74

Hauling beets with four horses.

Farm 25 in 1924 planted beets in potato and bean ground. The land of this farm is fairly heavy which necessitated plowing. A good seedbed was prepared by frequent harrowing. Beets were irrigated six times this particular year due to the fact that the season was fairly dry. Good yields were secured due to rotation methods and frequent applications of manure. Plowing on this farm increases the labor input over that of farm 12.

Farm 17 plowed the land for beets. The practice was to manure grain stubble during August. The land would be disced thoroly, incorporating the manure into the soil. Later when moisture conditions were right the land was fall plowed. Seedbed preparation in the spring consisted of harrowing and leveling. A good firm seedbed was thereby secured. Irrigation water was applied from three to five times per season, depending on type of soil and the particular season. A tractor has been added to the farm equipment in order that the ground may be prepared at the right time. Deeper plowing has also been the practice since the purchase of the tractor. A truck has also been purchased which in the opinion of the operator has aided in reducing the cost of producing beets.

The practice in growing sugar beets on farm 5 was to follow potatoes by beets. Some years it was necessary to follow beets by beets. In this event the land was spring plowed and manured. All work was done by horses, no tractor being owned. Due to distance from the beet dump (3½ miles), a truck has been purchased which facilitates beet harvest. In the years 1924 and 1925 the cost to farm 5 was 78 cents per ton to haul beets to the beet dump. In the 3 years, 1926 to 1928 inclusive, when a truck was used, this cost

Hauling beets by truck may aid in lowering the cost of marketing.

was reduced to 65 cents per ton or a saving of $2.57 per acre for a 19.77 ton yield.

Table 24, which gives the results on all farms where records were available for over 4 years, shows that farm 12 used less hours of man labor per acre on beets for a period of 5 years than any other farm. The use of horse hours was relatively efficient also. Farm 11 also used a low number of man hours and less horse hours than farm 12. Rotation methods are responsible for these low labor requirements since these two farms rather consistently follow the practice of planting beets after some other cultivated crop without plowing.

Table 24.—Average for Farms Growing Sugar Beets 5 Years or More

Farm No.	No. of years	Acres planted	Acres harvested	Production per acre tons	Hours per acre			Operating costs	Total costs
					Man	Horse	Tractor		
5	5	22.17	20.77	19.77	43.73	96.97	....	$78.23	$96.03
11	5	28.98	24.95	17.14	30.69	62.81	....	68.20	88.66
12	5	55.45	55.01	15.94	27.89	71.54	....	64.35	76.23
13	5	50.58	39.53	17.48	37.76	96.24	.49	77.72	91.96
17	5	41.40	39.01	16.56	40.12	78.34	3.12	74.80	81.92
25	5	18.98	15.25	19.25	36.27	98.00	....	78.89	93.04
26	6	32.36	29.56	13.91	38.84	65.90	....	71.47	88.19
27	6	19.66	16.42	12.62	45.64	90.36	....	77.54	84.06

Normal Sugar-beet Costs.—In order to show what would be the result under conditions that exist over a wide area of Northern Colorado, a few changes were made in the 1926 year's costs to make them conform as far as possible to normal practice.

Out of 746.83 acres in sugar beets in 1926 only 329 acres were plowed. Taking the actual time for plowing 329 acres as a basis and using the average rates for man, horse, equipment, tractor and overhead costs, it was found that the cost per acre in 1926 would have been increased $4.39 if all the land had been plowed.

If the yield had been 14.4 tons per acre[1] instead of 18.51 tons there would have been certain savings. The extra bonus for topping beets would have been saved on 4.11 tons. This amounts to $2.06. These 4.11 tons would not have been hauled to the beet dump, a further saving of $2.71, as it cost 65 cents per ton to haul beets to the dump based on all records.

Hence a normal beet crop of 14.4 tons per acre based on the 1926 practice would cost $82.20 per acre without interest, or $95.72 including interest. This amounts to $5.71 operating cost per ton and $6.65 total cost.

A similar comparison based on all the records for the 6 years

[1]This was the average yield in Northern Colorado in 1926.

shows that a 13-ton yield would show $73.91 operating cost per acre and $87.68 total costs, or $5.68 operating costs per ton and $6.74 total costs per ton. These two figures are interesting as showing what might be expected with average yields and normal practice.

Twenty farm records out of 75 actually showed costs per ton greater than these computed averages so that they appear reasonable.

The difficulty of using these or any other costs as normal lies in the fact that no one farm any year is normal. Something is out of line. Extra work on this or that operation, higher water costs, changes in method, all tend to upset any normal. Take the one item of changes in method. Tractors are coming into the region. What effect will they have on costs per acre? Trucks are being used to haul to the beet dump. How are their costs compared to the use of teams? Pumping plants are coming to supplement reservoir water. What is the cost of pumped water?

Hence with these costs, they should be used as a starting point and each farmer can then make such changes as make them conform more closely to his conditions. In that way he will come nearer the truth than if he relies blindly on an "average."

Profit or loss per acre is not necessarily a reliable guide as to whether, if the particular crop were increased in acreage, say doubled, the total net profit from the doubled acreage would be two-fold. It might be greater or less than this. However, in determining how far one should increase or decrease his production he should take into consideration not only the one particular crop but the entire combination of crops raised on his farm. Labor distribution, extra machinery, rotation practices all need to be considered.

If the individual farmer can, by varying his inputs of labor, material, etc., secure greater proportionate yields with less proportionate expense of production, his profits per acre may be greater proportionately than his increase in expenses. If this be the case then he has not reached the point of diminishing returns for that particular crop. In seeking greater profit he should be careful his costs do not exceed his returns.

Barley.—Table 25 gives the average yearly results from raising barley. The year 1927 was the best year for all farms so far as yield was concerned. A crop over 400 pounds larger than any other year was produced at no greater cost per 100 pounds. The years 1924 and 1927 were the only years that barley paid all the costs of production, including interest on investment. In 1922, 1925 and 1926 the value of the crop barely equalled the operating costs, leaving nothing for interest.

Here is a crop that seldom is produced at a profit, yet persistently grown. Why? Farmers will tell you that they grow barley for feed. Agronomists will tell you that it is needed as a nurse crop for alfalfa. The facts are, if one refers back to the table showing cash costs, that barley produces more than enough to pay cash costs. It is a good feed and nurse crop. A farmer can grow it in addition to the area of potatoes, beets and alfalfa that he can handle, and practically with the same horses and equipment. It can be planted and harvested when other crops do not need attention. Consequently it remains in the rotation because there is nothing better to take its place.

Table 25.—Cost Per Acre of Producing Barley, 1922 to 1927

	1922	1923	1924	1925	1926	1927	Yearly average
Number of farms........	13	15	14	15	16	8	....
Acres in crop harvested...	20.62	25.24	27.54	24.50	29.58	17.01	24.08
Yield per acre, lbs........	2,187	2,402	2,427	1,822	2,314	2,869	2,337
Seed per acre...........	95	90	79	87	66	86	84
Man hours per acre......	14.72	13.37	13.58	13.05	17.00	12.90	14.10
Horse hours per acre.....	24.69	20.94	19.52	22.26	22.43	16.48	21.05
Tractor hours per acre....	.09	.69	.47	.41	.80	.34	....
Cost per acre:							
Man labor	$ 4.83	$ 4.26	$ 4.67	$ 4.43	$ 5.94	$ 3.67	$ 4.63
Horse labor	3.40	2.58	2.75	3.34	3.02	2.25	2.89
Seed	1.11	1.15	.99	1.64	1.02	.99	1.15
Manure	2.68	2.50	3.56	4.84	3.59	3.09	3.38
Twine	.42	.49	.44	.48	.56	.44	.47
Sacks	....	....	.10	.07	.07	.10	.06
Coal	.11	.11	.20	.12	.07	.06	.11
Threshing	4.04	4.34	4.13	2.02	3.01	3.89	3.57
Water tax	1.45	.49	.56	1.11	1.16	1.03	.97
Real estate tax........	3.68	3.13	2.77	2.68	2.73	3.45	3.07
Buildings	.30	.26	.69	.60	.44	.97	.55
Equipment	1.11	.94	.94	1.15	1.18	1.26	1.10
Tractor	.07	.54	.33	.29	.67	1.04	.49
Miscellaneous	.01	.11	.07	.14	.50	.27	.18
Overhead	1.34	1.03	1.09	1.52	1.86	1.51	1.39
Total operating cost......	24.55	21.93	23.29	24.43	25.82	24.02	24.01
Interest on land........	16.05	13.28	12.23	13.25	12.20	13.96	13.49
Total all costs...........	40.60	35.21	35.52	37.68	38.02	37.98	37.50
Value per cwt............	1.13	1.11	1.56	1.36	1.10	1.36	1.27
Value per acre...........	24.71	26.66	37.86	24.78	25.45	39.02	29.75
Returns per acre:							
Without interest	.16	4.73	14.57	.35	—.37	15.00	5.74
With interest	—15.89	—8.55	2.34	—12.90	—12.57	1.04	—7.75
Costs per cwt.:							
Without interest	1.12	.91	.96	1.34	1.12	.84	1.03
With interest	1.86	1.47	1.47	2.07	1.64	1.32	1.60

Thirty records out of the total for the 6 years showed operating costs less than $1.00 per 100 pounds. The price of barley seldom falls below $1.00. In fact, with corn above $1.50 per 100,

farmers can afford to raise barley because barley has a feeding value about the same as corn.[1] The saving in the feed bill will balance the apparent loss on the barley. The farm as a whole will be ahead.

This emphasizes another phase of the use of crop costs. It is of doubtful value to consider the farm as made up of separate crops. It should be viewed as a whole. One crop may be necessary in the rotation in producing another crop.

Beets require exceptional care. Grain and hay in the rotation may be continued at a loss because they are necessary to complete the rotation.

Table 26 shows the results on farms where barley records were obtained 4 or more years. Farm 29 had the best yield, farm 17 the lowest cost per acre, and the least time per acre, due to the efficient use of both horses and tractor.

Table 26.—Farms Growing Barley 4 or More Years

Farm No.	No. years	Acres harvested	Yield per acre lbs.	Hours for acre Man	Horse	Tractor	Costs per acre Operating	Total
5	6	13.61	2892	16.7	27.8	....	$28.52	$45.89
12	5	43.47	2168	15.3	21.6	....	21.49	32.93
13	5	69.41	1999	16.2	27.3	.48	24.28	37.90
17	5	52.97	2558	12.0	11.5	2.17	20.90	27.27
26	6	18.39	1993	12.4	20.0	....	23.74	39.91
27	6	13.41	2008	14.7	23.5	....	24.25	31.15
29	4	7.97	3086	18.3	30.0	....	35.10	56.97
33	4	19.50	2654	17.7	23.4	.22	31.96	39.84
34	4	36.54	3028	12.4	14.6	.60	26.87	42.27

Alfalfa.—This is the only crop that every farmer grew every year, yet only 1 year out of 6 did it pay all expenses. In 1924 alfalfa was worth practically $15 per ton and showed a small profit as a consequence. See Table 27.

The yields for three cuttings were close to 2½ tons per acre. These yields were based on measured stacks, not on actual weights. Some farmers used one formula for measuring hay, some used another, but in most cases one-fourth of the over times the width times the length; this result divided by 512 was used for finding the tonnage. Experiments by J. W. Sjogren of the Colorado Agricultural College, and work in other states suggests that for all except the low, squatty stacks this rule underestimates the tons in a stack. If this is true the actual yields in this area as found by scale weights would have run higher than shown.

Most of the hay produced in this area is fed on the farms. In

[1]E. J. Maynard, Colorado Experiment Station.

this case the question of measuring stacks is of minor importance. On farms where hay is sold, it becomes of major importance. The whole purpose of a rule for measuring stacks is to find some easy method to determine the cubic contents of the stack, then to determine the number of cubic feet per ton. When one considers the number of things which cause variations in results, it is apparent that any rule is a makeshift. The best method is to weigh the hay when it is sold. This eliminates the chance of either party getting an advantage.

Table 27.—Average Yearly Cost Per Acre of Producing Alfalfa, 1922 to 1927

	1922	1923	1924	1925	1926	1927	Yearly average
Number of farms	22	22	20	22	19	9	....
Acres in crop	43.37	48.52	53.47	48.09	49.25	49.20	48.65
Yield per acre, tons	2.62	2.64	2.41	2.37	2.68	2.09	2.47
Man hours per acre	14.32	16.50	16.03	16.94	18.79	14.43	16.17
Horse hours per acre	20.02	19.11	18.61	23.02	23.10	18.87	20.46
Cost per acre:							
Man labor	$ 4.67	$ 5.34	$ 5.63	$ 5.55	$ 6.50	$ 4.44	$ 5.35
Horse labor	2.93	2.67	2.86	3.50	3.16	2.39	2.92
Seed	.70	1.22	.98	1.48	1.11	.76	1.04
Manure	2.19	3.57	2.17	3.87	2.72	2.29	2.80
Water tax	1.27	1.38	1.21	1.44	1.28	1.17	1.30
Real estate tax	3.41	2.97	2.90	2.56	2.87	2.98	2.95
Equipment	.95	.93	.95	1.33	1.31	1.43	1.15
Miscellaneous	.02	.02	.09	.16	.05	.06	....
Overhead	1.17	1.41	1.45	1.60	2.08	1.74	1.57
Total operating cost	17.31	19.51	18.24	21.49	21.08	17.20	19.14
Interest on land	15.12	14.10	13.68	14.14	12.23	11.78	13.51
Total all costs	32.43	33.61	31.92	35.63	33.31	28.98	32.65
Value per ton	11.91	10.65	14.87	13.83	7.66	10.45	11.51
Value per acre	31.20	28.12	36.13	32.78	20.53	21.84	28.43
Returns per acre:							
Without interest	13.89	8.61	17.89	11.29	—0.55	4.64	9.29
With interest	—1.23	—5.49	4.21	—2.85	—12.78	—7.14	—4.22
Costs per ton:							
Without interest	6.61	7.39	7.57	9.07	7.86	8.23	7.75
With interest	12.38	12.73	13.25	15.05	—12.44	13.87	13.22

Table 28 gives the area, yield and costs per acre for growing alfalfa on all farms with records over four years. Farm 25 had the highest average yield. Farm 12 had the lowest hours per acre, and the lowest operating costs.

Alfalfa is recognized as an essential part of any crop rotation. Yet as the years pass it seems to become increasingly difficult to secure a stand. The years 1924 and 1925 were the worst in the history of the valley. Since then better stands have been secured.

The general opinion based upon the 1924 experience seemed to be that there were two outstanding reasons for the increased difficulty in securing a stand of alfalfa: First, the fact that long use

of manure and better rotations had increased the richness of the soil so that more leaf and stem growth on barley and other grain tended to smother the alfalfa seedlings; second, the nurse-crop grains have always been planted from the point of view of getting a good yield of grain, and not from the point of view of securing a good stand of alfalfa.

In 1924 many fields showed alfalfa plants that came up, then smothered, or other fields where the plants were so weak that they died soon after grain harvest. However, these do not explain the difficulties with the alfalfa crop as a whole.

Corn or sorghum provide excellent roughage when alfalfa fails.

Table 28.—Average for Farms Growing Alfalfa Four or More Years

Farm No.	No. Years	Acres in alfalfa	Tons per acre	Hours per acre			Cost per acre	
				Man	Horse	Tractor	Operating	Total
1	4	28.89	2.61	14.50	16.40	....	$18.19	$30.71
2	4	23.46	2.79	21.00	23.20	....	24.47	36.42
5	6	44.87	2.28	16.30	20.60	....	19.37	36.78
6	4	30.69	1.98	20.10	18.60	....	19.18	34.86
11	5	41.49	2.70	17.10	20.95	....	22.46	42.03
12	5	89.69	2.15	10.58	16.27	....	14.18	25.82
13	6	83.68	2.60	14.73	21.31	....	19.18	32.37
17	5	74.79	2.06	16.40	20.33	.68	17.25	23.65
25	5	36.68	3.41	18.74	25.51	....	23.78	36.93
26	6	37.93	2.87	17.58	25.07	....	23.14	39.51
27	6	18.33	2.55	14.49	19.84	....	17.62	24.08
28	6	39.76	3.04	17.88	17.70	....	20.67	34.55
29	5	56.51	2.24	13.60	14.33	....	20.07	36.68
33	4	66.00	2.25	15.02	17.62	....	18.95	26.76

Probably the most important difficulty is that of securing a stand of alfalfa for a period longer than 3 years. Experience during the past few years indicates that the rotation may have to be shortened. This may eventually be beneficial inasmuch as all the farm will be rotated whereas previously there has been a tendency to plant particular fields better adapted to certain crops several years in succession. As a result the nematode disease of beets and various potato diseases have tended to increase somewhat rapidly. Yields have become less while the quality of product has decreased. Therefore rotating the entire farm may in the years to come actually increase the normal production.

The causes of the difficulty of maintaining a stand of alfalfa are several in number. Within the past few years a bacterium wilt has become more noticeable in its effects. This muds or clogs the vascular system of the roots of the alfalfa plants, causing a continual dropping of the leaves and shortening the stems. Because of this, plant food fails to enter the stem and leaves, thus reducing plant growth and thereby yield. Another factor is that of winter killing. It is impossible to determine how much the yield of alfalfa is reduced by these two causes.

It is also possible that with continued applications of irrigation waters the amount of salts in the soil may have become increased, which also may aid in the so-called clogging of the vascular system of the alfalfa roots. It has not as yet been definitely determined whether the clogging is wholly that of the bacterium, or partly that of the collection of salts, or both. Evidence is at hand which tends to show that the disease may be somewhat more prevalent where heavy applications of irrigation water are supplied to the alfalfa.[1]

Another cause is that of planting poor seed. When alfalfa was first planted in Northern Colorado the seed mostly came from Hamburg, Germany. This was exceptionally good seed. Of late years seed has been used from other foreign countries such as Argentine, Turkestan and from various locations within the United States, and has not been adapted to climatic and soil conditions of Northern Colorado.

Failure to plant the better grades and varieties of alfalfa may be somewhat responsible for increased winter killing or bacterium wilt. Some farmers who have shown care in the selection of alfalfa seed, and in their methods of seeding, have had no trouble with alfalfa stands during the period of this study.

In the last few years some farmers have used Grimm alfalfa seed in order to secure a better stand of hay.

[1]L. W. Durrell, Colorado Experiment Station.

The cost of producing alfalfa is influenced by the methods of handling the crop. One of these methods is that of irrigation practice and the corresponding labor involved. Some farmers practice more or less consistently the irrigation of alfalfa at night. Nearly all farmers practice this method to some extent, some more than others. This practice depends largely on the amount of water to be had, the proportion of grain and row crops to alfalfa, and the lay of the land.

A large supply of water will be allowed to run on alfalfa longer than a more limited supply. Therefore the labor requirements are reduced in making sets. Especially is this the case in night sets. A larger proportion of grain or row crops relative to the alfalfa acreage results in day sets of water on the grain or row crops and night sets on the alfalfa, thus reducing the labor requirements on the alfalfa.

Another variation in practice is in the method of stacking. Two methods of stacking alfalfa are followed in the Eaton-Greeley area. Near Greeley the crane stackers and sleds are used. This method necessitates the use of three sleds pulled by two horses per sled, in order to keep the stacker occupied. Three teamsters and at least one field pitcher are necessary in addition to the men at the stack. Ten to 15 acres will normally be stacked in a day's time with such a crew

In the Eaton-Severance area the overshot stacker is the more common practice. Three sweeps and a stacker team driven by a boy, with two men on the stack, will normally stack 14 to 20 acres

Buck rakes and an overshot stacker save labor in stacking alfalfa according to data secured in this study.

per day. The latter method is less expensive while the former method results in better quality of hay and less wastage about the stacks. Especially is this true if the season is at all wet.

For the year 1926 four men were selected who used one method, and four who used the other. Farms 11, 25, 31 and 38 used the sled and crane stacker. Farms 5, 13, 26 and 28 used the buck rake and overshot stacker. The results on the two groups of farms were as follows:

Table 29.—Hours Labor Stacking Hay by Different Methods, 1926

Item	Sled stacking		Buck rake stacking	
Number of farms........	4		4	
Area alfalfa	176.5		216.9	
Yield per acre, tons......	3.6		2.2	
Hours per acre	Man	Horse	Man	Horse
For three cuttings.....	14.51	17.46	6.05	8.23
For one cutting.......	4.84	5.82	2.02	2.74
Hours per ton...........	4.04	4.86	2.75	3.74

Getting a load of hay with sleds and slings. This takes more time than with rakes.

The time per acre for the group using sleds should be more than for the others, as the yield per acre was 1.4 tons greater. Even when put on a ton basis, however, the buck rake method shows a saving of 1.29 man and 1.12 horse hours per ton. At average rates for man, horse, equipment and overhead, this means a saving in labor per ton of about 75 cents for the buck rake method as compared to the use of sleds.

Variation in the cost of producing a ton of alfalfa is there-

fore partly due to failure in securing a stand, and partly to different ways of irrigating and stacking.

Beans.—The bean crop is normally a crop which is planted in lieu of some other cultivated crop, which may, because of climatic conditions, be unprofitable to cultivate that particular year. The land can be worked at small cost and planted to beans later in the season. This crop therefore serves the purpose of being a catch crop which brings in some ready money during the season. Many farmers planting beans under these conditions consider that any return over and above actual prime costs is that much gained, as the land might be otherwise idle or planted to some feed crop which may not be needed the year in question.

Beans may also be planted on land not suited for potatoes or beets or may replace a portion of these crops any given year, should the cultivated acreage of these crops be exceptionally large in proportion to the total cultivated area. In the case of land not suited for potatoes or beets, beans, being a cash crop, will supply a portion of the operating expenses and yield a financial return comparable with a poor beet or potato crop. In the case of beans replacing a portion of the beet or potato acreage, the question of supply of irrigation water becomes a factor inasmuch as beans require less water than potatoes or beets. Beets the year following beans receive but little soil preparation as it is seldom necessary to plow. Bean growers who consistently plant a small portion of their farm to beans therefore find serious competition some years from those who continually change their policy as to growing beans.

Two types of beans were grown in this area. Pinto or Mexican beans, and seed beans, so-called, which include all varieties of beans grown under contract for seed houses. Table 30 shows the average results for 4 years on pinto beans. Table 31 shows the result with seed beans for 3 years. In the years 1922 and 1923 no separation was made between the two kinds of beans. There were 12 records these years. The average for the 12 showed a loss of 57 cents per acre without any interest, and a loss of $14.30 per acre when interest was included. Neither of these years offers any suggestion or hope of profit, altho farm 14 did make a profit each year.

In 1925 and 1926 pinto beans made more money than seed beans. In 1924 seed beans did the better. In 1924 and 1927 pinto beans were very poor. Blight and rust nearly ruined the crop.

Considering all records and years, the bean crop at yields and prices existing during this study was not a profitable crop. Pinto beans in 1926 and seed beans in 1924 were the only instances where they paid interest on the investment in land.

Because beans are grown to fill a gap, so to speak, in the cropping program, the supply fluctuates considerably, with the result that wide variations in price occur. Especially is this true of pinto beans which are grown extensively in the more arid sections of Colorado as well as on irrigated farms. Cost records kept by 17 farmers during 1926 and 1928 on dry land[3] show that $4.53 per 100 pounds is necessary to meet all expenses of production, including interest on investment. A comparison of this figure with that in Table 30 shows that only 1 year out of the 4 were farmers on irrigated farms able to meet this comparative price.

Table 30.—Average Yearly Cost Per Acre of Producing Pinto Beans, 1924 to 1927

	1924	1925	1926	1927	Yearly average
Number of farms	2	6	3	4	....
Acres in crop	5.34	14.74	9.73	11.03	10.21
Yield per acre, lbs.	251	1,156	1,085	154	662
Seed per acre	17	24	41	55[1]	34.2[2]
Man hours per acre	24.18	32.63	45.52	51.79	38.53
Horse hours per acre	36.18	30.41	48.41	75.29	47.57
Tractor hours per acre	....	.11	....	1.09	.30
Cost per acre:					
Man labor	$ 8.85	$10.56	$14.40	$15.78	$12.40
Horse labor	5.96	5.00	6.56	7.51	6.26
Seed	.85	1.59	1.64	4.24	2.08
Manure	.14	.78	.98	.65	.64
Coal	....	.10	.17	....	.07
Threshing	.95	3.83	3.02	1.63	2.36
Water tax	....	1.55	1.79	5.23	2.14
Real estate tax	3.26	2.25	3.14	5.52	3.54
Equipment	2.29	1.51	2.64	4.14	2.65
Tractor	....	.12	....	1.85	.50
Miscellaneous	.05	.55	.14	.15	.21
Overhead	2.66	3.08	3.61	6.47	3.95
Total operating cost	25.01	30.92	38.09	53.17	36.80
Interest on land	12.88	11.24	13.57	24.23	15.48
Total all costs	37.89	42.16	51.66	77.40	52.28
Value per cwt.	4.61	3.58	5.00	4.94	4.34
Value per acre	11.59	41.38	54.25	7.59	28.70
Returns per acre:					
Without interest	—13.42	10.46	16.16	—45.58	—8.10
With interest	—26.30	—.78	2.59	—69.81	—23.58
Cost per cwt.:					
Without interest	9.95	2.67	3.51	34.52	5.56
With interest	15.07	3.65	4.76	50.26	7.91

[1]28 lbs. per acre planted; 87.80 acres planted; 44.11 acres harvested.
[2]28 lbs. per acre based on area planted.

[3]T. H. Summers, Colorado Extension Service.

In the absence of disease, pinto beans are a profitable crop.

Table 31.—Yearly Average Cost Per Acre of Producing Seed Beans, 1924 to 1926

	1924	1925	1926	Yearly average
Number of farms	5	9	4	....
Acres in crop	15.26	20.23	14.12	16.54
Yield per acre, lbs.	1,427	919	905	1,084
Seed per acre	60	52	71	61
Man hours per acre	34.9	36.89	40.25	37.35
Horse hours per acre	50.0	35.22	43.90	43.04
Cost per acre:				
Man labor	$12.59	$12.13	$13.18	$12.63
Horse labor	8.91	6.11	5.84	6.95
Seed	2.88	2.57	3.48	2.98
Manure	.60	.88	.33	.60
Coal	.21	.04	.04	.10
Threshing	5.00	3.35	3.13	3.83
Water tax	1.93	3.36	2.99	2.76
Real estate tax	2.87	2.96	3.19	3.01
Equipment	3.10	2.00	2.49	2.53
Miscellaneous	.17	.17	.22	.19
Overhead	3.15	3.03	4.07	3.41
Total operating cost	41.41	36.60	38.96	38.99
Interest on land	15.41	15.28	14.64	15.08
Total all costs	56.82	51.80	53.60	54.07
Value per cwt.	4.56	4.88	4.89	4.74
Value per acre	65.10	44.84	44.25	51.40
Returns per acre:				
Without interest	23.69	8.24	5.29	12.41
With interest	8.28	—6.96	—9.35	—2.67
Costs per cwt.:				
Without interest	2.90	3.98	4.30	3.40
With interest	4.56	5.64	5.92	4.99

Oats.—Fifty-five records were secured on oats during the 6 years. The average results each year are shown in Table 32. Each

year they failed to earn interest on the average investment in land. A few farms were able to grow oats at a profit, notably 12, 25 and 38. These results were secured by men who had shown the ability to produce other crops at a profit when some of their neighbors were scarcely breaking even. But their profits were small. Oats have little to recommend them for wide use under conditions that obtain in this region. They do not yield as heavily as barley; are not as good a nurse crop for alfalfa; and apparently do not offer as much chance for profit.

They do supply a certain need in furnishing feed for horses. Probably in this respect they are superior to barley, which is the more general horse feed, mainly because farmers do not like to bother with a few acres of oats just for the work stock.

Table 32.—Average Yearly Cost Per Acre of Producing Oats, 1922 to 1927

	1922	1923	1924	1925	1926	1927	Yearly average
Number of farms	9	12	11	11	8	4	....
Acres in crop harvested	9.57	11.21	14.67	17.26	16.55	10.97	13.37
Yield per acre, lbs.	1,892	1,906	1,798	1,887	2,527	1,802	1,968.6
Seed per acre	81	100	68	104	69	93	85.8
Man hours per acre	17.20	13.26	13.31	12.47	13.53	12.03	13.6
Horse hours per acre	26.59	17.42	16.95	21.45	18.61	16.59	19.6
Tractor	....	.16	....	.20	....	....	.06
Cost per acre:							
Man labor	$ 5.32	$ 4.45	$ 4.75	$ 4.44	$ 4.74	$ 3.42	$ 4.52
Horse labor	4.67	2.63	2.56	3.54	2.80	2.14	3.06
Seed	1.14	1.09	1.20	2.02	1.15	1.24	1.31
Manure	1.92	1.94	2.48	4.50	3.54	2.79	2.86
Twine	.47	.45	.53	.49	.60	.40	.49
Coal	.39	.15	.20	.10	.08	....	.15
Threshing	3.94	4.28	3.25	4.08	4.57	3.73	3.97
Water tax	1.40	.95	.79	1.33	1.18	1.16	1.13
Real estate tax	3.78	2.77	2.62	3.21	2.75	3.33	3.08
Buildings	.34	.20	.56	.53	.40	.24	.38
Equipment	1.28	.69	.85	1.12	.94	1.18	1.01
Tractor	....	.19	....	....	.07	....	.04
Miscellaneous	.11	.08	.11	.23	.41	.36	.22
Overhead	1.13	1.06	1.04	1.19	1.83	1.60	1.31
Total operating cost	25.89	20.93	20.94	26.78	25.06	21.59	23.53
Interest on land	17.14	14.16	13.80	17.96	12.76	14.14	14.99
Total all costs	43.03	35.09	34.74	44.74	37.82	35.73	38.52
Value per cwt.	1.43	1.42	1.66	1.53	1.32	1.60	1.48
Value per acre	27.06	27.06	29.85	28.87	33.36	28.83	29.17
Returns per acre:							
Without interest	1.17	6.13	8.91	2.09	8.30	7.24	5.64
With interest	—15.97	—8.03	—4.89	—15.87	—4.46	—6.90	—9.35
Cost per cwt.:							
Without interest	1.37	1.10	1.16	1.42	.99	1.20	1.20
With interest	2.27	1.84	1.93	2.37	1.50	1.98	1.96

Wheat.—There was much variation in the importance of wheat in this area from year to year. Wheat is a cash crop that can be

Harvesting an excellent crop of oats.

grown in place of other cash crops. When prices of wheat looked attractive, or prices of other crops did not look attractive, then more wheat was grown. In 1922 15 farms grew wheat. In 1924 only 2 farms grew wheat. And, as such things have a habit of doing, the results in 1922 were the poorest and those in 1924 were the best. In 1922 nobody made money on wheat.

In 1927, with yields 470 pounds per acre less than in 1926,

Wheat serves as one of the minor cash crops in the Greeley area.

there was $3.12 more profit per acre. This was due to decreased costs in 1927. Less labor, less other costs, more than offset the reduced yield.

On the whole wheat has a place on these farms. It showed a profit 4 years out of 6 but averaged a loss for all records studied because the 2 years with a loss had such heavy losses. The price apparently should be at least $1.75 per 100 pounds or over $1.00 per bushel before it offers much chance of profit.

At the price of $1.75 per cwt. one must secure 37 bushels of marketable wheat in order to secure wages for himself and return for use of land. Wheat must be produced in competition with other sections of the United States which have comparative advantages in labor requirements, large scale machinery, less overhead, and a lower necessary return for use of land to keep the supply forth-

Table 33.—Average Yearly Cost Per Acre of Producing Wheat, 1922 to 1927

	1922	1923	1924	1925	1926	1927	Yearly average
Number of farms........	15	12	2	9	9	4	....
Acres in crop harvested...	27.44	23.77	12.50	13.77	20.14	17.65	19.21
Yield per acre, lbs........	1,552	1,718	2,348	1,687	2,686	2,218	2,034.8
Seed per acre...........	76	84	86	94	75	82	82.8
Man hours per acre.......	13.32	11.22	16.99	12.14	17.24	11.82	13.79
Horse hours per acre.....	18.57	15.12	17.28	18.18	28.96	14.74	18.81
Tractor hours per acre....	.08	.11	....	.19	.20	....	.10
Costs per acre:							
Man labor	$ 4.50	$ 3.82	$ 6.40	$ 4.15	$ 6.31	$ 3.85	$ 4.84
Horse labor	2.92	2.15	2.94	3.05	4.28	2.05	2.90
Haul contract	....	....	.65	.06	.07	.30	.18
Seed	1.48	1.40	1.45	2.88	1.97	1.69	1.81
Manure	2.40	1.66	3.29	4.23	3.94	2.12	8.61
Twine	.46	.51	.52	.40	.98	.56	.57
Coal	.23	.21	.13	.23	.14	.08	.17
Threshing	2.72	3.20	4.92	3.21	5.05	4.16	3.88
Water tax	1.50	.77	.67	.78	1.01	.75	.91
Real estate tax........	3.14	2.96	2.88	3.08	3.30	3.05	3.07
Buildings	.27	.23	.11	.06	.10	....	.13
Equipment	.94	.73	.96	1.22	1.62	.97	1.07
Tractor	.20	.14	....	.11	.15	....	.10
Miscellaneous	.25	.06	.13	.04	.32	.55	.23
Overhead	1.01	1.01	1.41	1.12	1.90	1.51	1.33
Total operating cost......	22.02	18.85	26.46	24.62	31.14	21.64	24.12
Interest on land.......	14.86	14.44	10.45	17.12	15.45	13.40	14.29
Total all costs...........	36.88	33.29	36.91	41.74	46.59	35.04	38.41
Value per cwt............	1.45	1.38	1.91	2.48	1.80	1.80	1.81
Value per acre...........	22.50	23.71	44.85	41.84	48.35	39.92	36.86
Returns per acre:							
Without interest	.48	4.86	18.38	17.12	17.21	18.28	12.74
With interest	—14.38	—9.58	7.94	.10	1.76	4.88	—1.55
Cost per cwt.:							
Without interest	1.42	1.10	1.13	1.46	1.16	.97	1.18
With interest	2.38	1.94	1.57	2.47	1.73	1.57	1.89

coming. Wheat has a limited place on the irrigated farms of Colorado, after sufficient feed crops are grown and where the soil is not adapted to some other crops and where a cash crop is desirable.

The average yield has been, for the six years studied, about 33 bushels, or 4 bushels less than necessary to pay all expenses of production. Yields on the heavier soils of Northern Colorado irrigated farms are reported well above this necessary profit yield of 37 bushels.

As a cash crop, wheat in this area is superior to barley. The demand for barley as a sheep and cattle feed, however, results in a larger acreage being grown.

Corn.—Corn was not grown extensively any year, yet it was handled in many ways. One man grew silage corn every year. Some grew grain corn; some fed off the standing corn. In 1925 five men cut corn for fodder for sheep or cattle, two men grew popcorn. Because of the small number of records in each case, the only figures shown are the average results for each method of handling. Even these are of doubtful value because of the small number of records. In the case of silage corn, the result comes nearer to what might be called normal, as a definite place in the rotation was assigned to corn, and it had an equal chance with other crops. But even here the averages are low on yield. Fodder corn or fed-off corn was more of a fill-in crop to take the place of some crop that had been originally planned for.

The yield of silage corn shows as 8.09 tons per acre. This average is somewhat below normal, due to a low yield in 1925. The

Inspecting a field of corn on a farm-management tour.

farm where corn silage was grown every year is in a state of high fertility. The cornfields were the equal of any in the neighborhood, yet the measured yield as shown by weight tables for settled silage never went above 9 tons except 1 year, when the average was 10.16 tons. The value per ton for silage was $5.64. Compared to average alfalfa values this appears reasonable. Costs may appear high yet this same farm made a very good comparative showing in producing other crops. The conclusion is that silage does not pay in this region. Empty silos on some farms testify to the accuracy of this conclusion.

Table 34.—Average Cost of Producing Corn—All Records

Method of handling	Grain	Silage	Fodder	Fed-off	Popcorn
Number of records	13	8	5	7	2
Acres in crop harvested	7.67	12.98	17.63	16.29	21.19
Yield per acre	2,251 lbs.	8.09 T[1]	3.66 T	[2]	2,614 lbs.
Seed per acre, lbs.	12.4	11.2	17.0	10.7	contract
Man hours per acre	35.2	43.9	25.78	17.6	30.2
Horse hours per acre	58.8	66.6	36.21	29.4	49.6
Tractor hours per acre	....	....	1.06	.6	....
Costs per acre:					
Man labor	10.71	12.30	6.98	5.93	11.36
Horse labor	10.15	9.23	5.63	4.95	9.75
Hand contract	....	....	....	....	7.94
Seed	.67	.33	.82	.51	contract
Manure	2.51	6.15	6.41	1.46	4.45
Twine	....	.63	.14	....	....
Sacks	....	....	....	....	.71
Threshing	.93	....	....	....	....
Water tax	1.33	1.63	2.30	1.28	1.82
Real estate tax	3.68	3.41	2.97	2.39	2.18
Buildings	.62	4.53	....	....	.85
Equipment	2.49	3.67	2.82	1.91	2.15
Tractor	....	....	.58	.67	....
Miscellaneous	.26	2.80	.03	.09	....
Overhead	2.99	3.56	2.26	1.52	4.22
Total operating cost	36.34	48.24	30.94	20.71	45.43
Interest on land	17.13	15.99	13.08	15.25	9.44
Total all costs	53.47	64.23	44.02	35.96	54.87
Value per cwt. or ton	1.30	5.64	8.48	....	2.82
Value per acre	29.26	47.76[1]	31.02	24.12[2]	73.74
Returns per acre:					
Without interest	—7.08	—.48	.08	3.41	28.31
With interest	—24.21	—16.47	—13.00	—11.84	18.87
Cost per cwt. or ton:					
Without interest	1.61	6.77[3]	8.46	....	1.74
With interest	2.37	9.12[3]	12.02	....	2.10

[1]134 lbs. grain per acre picked before silo filled. Included in value per acre. Silage only $45.62 per acre.

[2]103 lbs. grain per acre picked before fed-off included in value per acre.

[3]Net after value of grain deducted.

Corn for grain averaged 2,251 pounds per acre or about 40 bushels. Good irrigated land is capable of yields much above this figure. Conservative opinion in the region claims that the yields shown here are about the same as yields of 10 tons of beets. If that is the case, 60 to 75 bushels of corn would be entirely within the possibilities where the same care is given that results in 15 to 20 tons of beets.

The question might arise as to whether barley or corn is the more profitable to grow. It is not so much a question of profitableness as it is a question of labor distribution. Corn cultivating interferes with beet and potato labor. Corn planting and harvesting tends to increase the peak load of labor in May and September. Furthermore, corn land requires additional labor over what barley land would for succeeding crops such as beets in that discing the corn row is necessary before plowing.

The cost of growing corn for pasture was $20.71 per acre without any charge for interest. It was valued at about $24 per acre, leaving only $3.41 return for the use of land.

Popcorn proved profitable on the two records shown. This is a poor guide to the future, as the market is easily flooded with popcorn. However, at prices of 2 cents per pound or better popcorn will give a fair return if these yields are normal.

Miscellaneous Crops.—Fourteen records on cabbage showed this crop to be profitable over a period of years. In 1922, 1923 and 1926 the cabbage crop resulted in a loss. These were all years of low prices. Whenever prices were 50 cents per 100 pounds or better

When cabbage is transplanted, immediate irrigation is necessary.

the crop returned a profit. The average yield on these records was nearly 12 tons per acre and the price a little over $10.00 per ton.

The high charge for hand contract labor is due to the method of handling the crop. In many instances the cabbage crop was rented out to someone who would do all the hand work and receive a share of the crop. For all records this share amounted to $47.75 per acre listed as contract labor. If this is deducted from $93.84, it gives $46.09 per acre as the operating cost to the owner and similarly $60.84 as the total cost.

Six records on canning factory peas gave a net profit per acre of $1.66. Four of the records failed to pay expenses, the other two made enough to offset the four and show an average profit for all records. The yield per acre on these two records was 2,370 pounds shelled peas per acre compared to 1,604 pounds for all records. The price was $3.64 per cwt., compared to a price of about $2.50 per 100 pounds other years.

The average cost per acre on all records was $47.61 or approximately $3.00 per hundred for a 1,604-pound yield.

Table 35.—Average Cost Per Acre of Producing Cabbage and Peas—All Records

Crop	Cabbage	Peas
Number of records	14	6
Acres in crop	9.16	16.26
Yield per acre, lbs.	23,471[1]	1,604
Seed per acre	....	90
Man hours per acre	43.77	17.6
Horse hours per acre	67.50	33.2
Tractor hours per acre	.55	....
Costs per acre:		
Man labor	$15.07	$ 6.08
Horse labor	7.72	5.62
Hand contract	47.75	6.07
Haul contract	.06	....
Seed	3.12	5.52
Manure	5.32	.32
Water tax	1.81	1.26
Real estate tax	2.87	2.87
Equipment	3.10	1.46
Tractor	.52	....
Truck	1.24	....
Miscellaneous	.57	.34
Overhead	4.69	2.08
Total operating cost	93.84	31.62
Interest on land	14.75	15.98
Total all costs	108.59	47.61
Value per cwt.	.534	3.07
Value per acre	116.65	49.27
Returns per acre:		
Without interest	22.81	17.65
With interest	8.06	1.66
Cost per cwt.:		
Without interest	.430	1.97
With interest	.497	2.97

[1]Based on 13 farms. On one farm no yield was reported.

Using a pea divider previous to harvest.

It would appear from these few records that yields of over 2,000 pounds per acre or prices of 3 cents per pound or better, were necessary in order to insure a profit on peas. Both of these are within the range of possibility. Hence the crop is worthy of more attention than it has had in previous years.

One decided advantage of the crop is the time of harvest. It

Trucks may enlarge the area over which peas may be grown.

brings in a cash income early in the summer when there is very little money coming in on the average farm.

Peas must be grown in relatively close proximity to the canning factory and therefore cannot be grown over a very large area.

The culture of peas, due to early harvest, allows the land to be double cropped, providing a feed crop cut for hay is grown. Cane or sudan grass or millet is an excellent combination with the pea crop.

Harvesting of peas is generally done by the canning factory except the cutting or pulling. Harvesting does, however, come at the same time as first cutting of alfalfa. Late peas do not interfere except with cultivation and irrigation of other crops.

1928 Crops.—The costs for 1928 for the important crops are shown in Table 36. The largest number of farms with complete costs for any one crop was six, hence the results for 1928 were not given equal weight in the averages previously discussed. The records are included here for comparison only. On the whole these results for 1928 agree closely with the records previously discussed.

Table 36.—Cost Per Acre of Producing Crops in 1928

Crop	Alfalfa	Barley	Oats	Wheat	Pinto beans	Sugar beets	Potatoes	Silage corn	Grain corn	Cabbage
Number of farms	6	6	5	2	2	2	6	1	1	1
Acres in crop	36.54	26.15	17.76	22.94	22.58	24.35	45.34	17.99	15.00	13.72
Yield per acre	2.09 T	2443 lbs.	2031 lbs.	1928 lbs.	796 lbs.	17.90 T	13,939 lbs.	4.21 T	45 bu.	27,248 lbs.
Man hours per acre	15.40	13.49	11.91	13.56	22.70	30.68	44.43	19.84	45.07	16.69
Horse hours per acre	18.74	20.21	21.52	6.89	32.40	57.85	65.37	28.52	32.67	39.87
Tractor hours per acre	.06	.31	.34	2.28	....	....	1.30	....	3.0	....
Costs per acre:										
Man labor	$ 4.78	$ 4.19	$ 3.48	$ 5.00	$ 7.28	$ 8.66	$14.06	$ 6.17	$12.30	$ 5.16
Horse labor	3.03	2.55	3.00	1.22	4.07	9.22	9.05	4.22	8.82	5.14
Hand contract	....	....	....	....	....	23.97	9.03	....	....	79.62
Haul contract	....	....	....	....	....	7.82	.55	....	....	7.69
Seed	2.05	1.31	1.67	1.45	2.85	3.00	9.33	.62	.58	.11
Manure	3.21	6.97	5.42	1.30	1.00	8.72	6.10	7.34	11.69	6.56
Twine	....	.47	.57	.42	....	....	.29	.39	....	....
Coal	....	.12	....	....	.17	....	....	....	....	....
Threshing	....	3.56	4.73	3.77	2.82	....	6.48[3]	4.20[2]	....	....
Water tax	1.25	.89	.66	.93	.31	3.07	2.55	2.58	.99	.36
Real estate tax	3.16	3.16	3.24	2.48	3.51	3.32	3.15	3.08	3.75	2.98
Buildings	....	.22	.33	....	....	.83	.68	3.65	....	....
Equipment	1.53	1.49	1.38	.50	3.05	4.29	5.28	2.14	3.44	2.14
Tractor	.10	.44	.33	.33[1]	....	....	.94	....	4.65	....
Truck	....	....	....	....	....	....	2.13	....	....	2.89
Miscellaneous	....	.20	.48	.43	.83	4.02	.28	2.50	....	....
Overhead	2.08	1.91	1.79	1.49	4.88	4.62	6.14	1.62	3.20	2.14
Total operating cost	21.19	27.48	27.08	19.32	30.77	81.54	76.04	38.51	49.42	114.79
Interest on land	14.97	15.23	13.77	13.05	11.58	15.03	14.45	16.82	15.74	14.01
Total all costs	36.16	42.71	40.85	32.37	42.35	96.57	90.49	55.33	65.16	128.80
Value per unit	16.05	1.15	1.43	1.385	5.42	7.00	.454	7.00	.82	.6075
Value per acre	33.54	28.19	29.04	26.70	43.14	125.30	52.30[4]	29.47	36.90	165.53
Returns per acre:										
Without interest	12.35	.71	1.96	7.38	12.37	43.76	—23.64	—9.04	—12.52	50.74
With interest	—2.62	—14.52	—11.81	—5.67	.79	28.73	—38.19	—25.86	—28.26	36.73
Cost per unit:										
Without interest	10.12	1.12	1.33	1.00	3.87	4.55	.66[4]	9.15	1.10 bu.	.421
With interest	17.26	1.75	2.01	1.68	5.32	5.39	.79[4]	13.15	1.45	.472

[1]This abnormally low cost for 2.28 tractor hours represents fuel and oil only. Farm 28 secured the use of a tractor free of charge.
[2]Filling silo.
[3]Sacks.
[4]Based on 11,519 lbs. accounted for.

Returns Per Hour of Man Labor.—In all the previous discussions the returns from each crop have been shown on an acre basis. To a farmer seeking the most profitable use of his time it is equally important to know which crop gives the best pay per hour for the time spent upon it.

Table 37 shows the average returns per man hour for the important crops based on the average for 6 years, 1922 to 1927. Sugar beets paid \$.9464 per hour; potatoes, \$.5898; and cabbage, \$.5284.

The significant thing about this table is the fact that, with the exception of barley, oats and pinto beans, every crop in this list gave some return per hour for the time spent on it. Where these crops can be grown without adding directly to the demand for more labor expenses, they offer some return for time that might otherwise be unused. Hence the total farm income will be increased altho it will be done at a low rate per hour for these particular crops such as alfalfa, seed beans and wheat.

For comparative purposes the net profit above all costs is shown for each crop in the last column. There were only four crops that paid all costs including interest and left a profit.

Table 37.—Average Returns Per Hour Man Labor for Important Crops

Crop	Return per acre for use labor	Hours per acre man labor	Return per hour man labor	Net profit per acre
Potatoes	\$31.52	53.44	\$.5898	\$13.63
Sugar beets	38.51	40.69	.9464	25.50
Barley	—3.12	14.10	—.2212	—7.75
Alfalfa	1.13	16.17	.0698	—4.22
Beans, seed	9.96	37.35	.2666	—2.67
Beans, pinto	—11.18	38.53	—.2901	—23.58
Oats	—4.83	13.60	—.3551	—9.35
Wheat	3.29	13.79	.2385	—1.55
Cabbage	23.13	43.77	.5284	8.06
Peas	7.74	17.60	.4397	1.66

Influence of Livestock on Crop Returns.—In the discussion of each crop in the preceding pages, no mention was made of any possible revenue from the straw, stubble or other waste products. As a matter of fact these crop residues are pastured by livestock in many instances. The value of sugar-beet tops was estimated to be from \$1.25 per acre up to \$7.00 per acre in different years. The average on 85 percent of the beet crop was \$4.19 per acre. For the 6 years, 1922 to 1927, the value of beet tops per acre in beets harvested was \$3.55. Hence \$3.55 should be added to the returns per acre shown.

Similarly the men estimated that alfalfa and grain-stubble

pasture was worth \$.95 per acre for all farms. And the value of straw used for feeders amounted to \$.30 per acre in grain. These pasture and feed values should be added to the return per acre of grain, and the pasture value of \$.95 should be added to the return per acre of alfalfa if one desires the total income from all sources from crops.

In the case of alfalfa and barley, livestock are largely responsible for the values placed on these crops. In years when few feeder sheep or cattle are fed in the area alfalfa drops to less than \$7.00 per ton. When feeding is normal, the price goes above \$15.00 per ton. Sale prices each year were used in showing the returns from crops.

Hours of Labor Used on Important Crops by Operations.— In the previous discussion of each crop the time required per acre has been shown as an average for each year and then a yearly average. In the following table the records for 6 years have been totalled and the labor on each crop for the period shown by operations. It will be noted that the total hours of labor per acre differ slightly in this table from that shown in the previous tables. Each acre is counted as one in getting these totals. Each year is counted as one in the other tables. To aid in comparison the time is shown as a sub-total up to harvest, then harvesting and marketing are shown separately.

The time actually spent manuring each crop is shown at the bottom and a new total given which includes manure. As previously noted, the cost of manuring crops on these farms was charged to each crop in proportion to the fertility removed, rather than in proportion to the time and manure directly used on each crop. Potatoes, sugar beets, corn and beans in the order named had the most time spent on them in applying manure. The number of records on cabbage was too small to separate them into two groups according to the method of handling the crop. An average composed of records where the farmer did all the work on cabbage along with records where the crop was rented out, would give a result with little meaning, consequently no labor figures are shown on cabbage. Actually more time was spent per acre applying manure to cabbage than to any other crop.

Some variation occurs between different crops for the same operation. This is due partly to the fact that the figures shown are based upon the entire acreage, while for some crops only part of the acreage was covered. In other cases there was a variation in the number of times the task was performed.

For example, plowing was a universal practice for potatoes. The average showed 4.7 man and 18.2 horse hours together with

0.5 tractor hours. Only a few men had tractors, and the time on their farms was not kept separate from the other farms. The time per acre plowing for beets was about one-half as much as for potatoes, because not over one-half of the land was plowed. More time was spent cultivating potatoes than beets. The time shown irrigating also includes the time cleaning and opening ditches, which explains the horse hours under this heading. Alfalfa and grain crops show about one-half as much time irrigating as was the case with beets and potatoes.

Table 38.—Hours Per Acre Producing Crops

Crop Acres in crop	Sugar Beets 2,638			Potatoes 2,739			Beans 666			Corn 460			Alfalfa 5,601			Barley 2,051			Oats 717			Wheat 1,109		
Average hours per acre	Man	Horse	Tractor	Man	Horse	Tractor	Man	Horse	Tractor	Man	Horse	Tractor	Man	Horse	Tractor	Man	Horse	Tractor	Man	Horse	Tractor	Man	Horse	Tractor
Operations:																								
Plowing	2.9	9.1	.5	4.7	18.2	.5	3.3	11.8	.1	3.8	12.5	.4	..	..	..	.7	1.8	.1	.5	1.7	.1	.6	2.2	..
Seedbed preparation	4.1	13.8	.1	2.6	8.5	..	3.0	9.9	..	3.2	9.3	.1	.2	.6	..	2.5	8.5	.2	2.2	7.6	..	2.4	8.0	.1
Planting	1.1	2.2	..	6.2	6.8	..	1.4	2.7	..	1.4	3.0	..	.3	.8	..	1.2	3.6	..	1.3	3.9	..	1.1	3.0	..
Cultivating	4.5	8.6	..	6.5	16.7	..	9.0	6.1	..	6.6	9.5	..	..	..	..	..	..	..	..	..	..	..	..	..
Irrigating	8.5	2.9	..	8.3	4.9	..	6.4	3.3	..	3.3	.9	..	3.7	.2	..	3.8	.7	..	4.0	.7	..	4.2	.7	..
Miscellaneous	.7	.4	..	.2	.1	..	.2	..	..	..	.1	..	..	..	..	..	..	..	.1	..	..	.1	.1	..
Sub-total till harvest	21.8	37.0	.6	28.5	55.2	.5	23.3	33.8	.1	18.3	35.3	.5	4.2	1.6	..	8.2	14.6	.3	8.1	13.9	.1	8.4	14.0	.1
Harvesting	5.8	14.9	..	5.2	14.1	..	12.1	7.6	..	..	..	..	12.1	19.0	..	6.0	6.6	.2	6.1	6.8	..	4.8	5.0	..
Marketing	12.0	30.0	..	18.9	11.3	..	.4	.6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total per acre	39.6	81.9	.6	52.6	80.6	.5	35.8	42.0	.1	..	..	..	16.3	20.6	..	14.2	21.2	.5	14.2	20.7	.1	13.2	19.0	.1
Manuring	3.2	7.1	..	5.0	11.6	..	1.9	4.7	..	..	..	..	.1	.1	..	.1	.3	..	.2	.3	..	.1	.2	..
Total including manure	42.8	89.0	.6	57.6	92.2	.5	37.7	46.7	.1	..	..	..	16.4	20.7	..	14.3	21.5	.5	14.4	21.0	.1	13.3	19.2	.1

Variations in Method of Handling Corn.—In the case of corn, the record given is up to harvest. All methods of handling corn are included, as there was little change in practice up to harvest regardless of how the crop was harvested. If corn was fed off, the extra labor would be charged to the livestock. On 86 acres of grain corn and 104 acres of silage corn the time spent in harvest was as follows:

Table 39.—Comparison of Hours Per Acre on Grain and Silage Corn

	Hours per acre	
	Man	Horse
Harvesting		
Grain corn	12.36	13.41
Silage corn	18.76	19.76
Total except manure[1]		
Grain corn	30.71	48.69
Silage corn	37.11	55.04
Total including manure[2]		
Grain corn	33.63	35.30
Silage corn	40.13	61.85

Rotations

The area of crops grown on all the farms included in this study indicates that about one-third of the crop area was in alfalfa, one-third equally divided between potatoes and beets, and one-third in grain and miscellaneous crops. This means a 6-year rotation Actually many farmers leave their alfalfa in one field as long as it yields anything at all and alternate their other crops in the balance of the fields until a new seeding of alfalfa is necessary.

It would be a wiser policy to keep alfalfa only 3 years and change the other crops more frequently. The failures of alfalfa seeding during the past few years have raised a question in the minds of farmers and students of farming as to how we can assure better success in the future. Better alfalfa seed; thinner seeding of nurse crop; irrigating so that seedling alfalfa plants are not left in soil too dry for their continued growth after the grain is harvested; keeping livestock off newly seeded alfalfa until the plants are firmly rooted; all these are necessary to secure good stands of alfalfa.

With these things in mind, experience in the region strongly recommends the following rotation: Alfalfa 3 years followed by potatoes, then by beets, then by grain reseeded to alfalfa. This gives one-half of the land in alfalfa. Where feeding is not favored

[1]Harvesting time plus hours up to harvest for all corn of 18.35 man hours and 35.26 horse hours.

[2]Includes 2.92 man hours and 6.81 horse hours per acre manuring all corn.

and more reliance must be placed upon cash crops, it seems that this rotation might be lengthened to alfalfa, 3 years; potatoes, 1 year; beets, 1 year; grain or beans, 1 year; beets, 1 year; and grain, 1 year, reseeded to alfalfa. This gives an 8-year rotation. When this rotation is followed it will be well to include a seeding of sweet clover in the grain crop between the two beet crops to furnish green manure for the second beet crop.

Where the new seeding of alfalfa fails and thus reduces the area of hay planned on for the next year, farmers are finding that cane, sudan or corn give a large amount of roughage. Men who shred corn fodder claim that it is an excellent feed when combined with alfalfa and concentrates.

Shredding corn fodder for cattle feed.

If the conditions at planting time are not favorable for sugar beets, cabbage or beans may be substituted for part of this acreage.

Potatoes are especially suited to the crop rotation systems in the area of Northern Colorado included in this study. Alfalfa is the principal hay crop. About every 3 years alfalfa must be plowed. The land has rested, so to speak, and is reasonably free from disease. The lateness with which potatoes may be planted allows for considerable green manure to be plowed under. This is ideal for potatoes, which respond to disease-free soil and green manures. The value of potatoes in rotation is still further realized the following year where beets may be planted on potato land without the necessity of plowing. Early seeding of beets can be accomplished, which increases the beet yield.

To find the effect of different rotations on returns, the per-

centage of cash and non-cash items of cost as previously discussed for the year 1926 were used as a basis and applied to the 5-year period, 1922 to 1926, inclusive. All costs except the farmer's own time were considered, and the return from the entire rotation was expressed as pay per hour for the farmer's time. The use of alfalfa, barley and other feed crops for feeding sheep or cattle and the possibility of extra profit from this source was not included. The figures were confined to the crop returns at 5-year average crop values. The results for different rotations are as follows:

Table 40.—Effect of Rotation upon Pay for Farmer's Time, Estimated from 5-Year Average Yields and Prices

Crop	No. years in rotation	Pay per hour for farmer's own time
Alfalfa	3	
Potatoes	1	
Beets	2	$.891
Wheat	1	
Alfalfa	3	
Wheat	1	
Beets	2	$.807
Barley	1	
Alfalfa	3	
Potatoes	1	
Beets	1	
Beans	1	$.752[1]
Beets	1	
Barley	1	

[1]By putting in wheat for beans this becomes $.781.

Controllable vs. Uncontrollable Factors

In all the previous discussion, comment has been made frequently showing the reasons why the growing of some crop resulted in a profit or a loss. These reasons might be summarized into two groups: First, those which the farmer can control, and second, those that are outside his immediate control. Some of the more important factors which are largely under the farmer's control are seed, cultural practices, timeliness of operations, use of irrigation water and productive capacity of the farm.

A factor that is important in affecting yield is that of pure seed. The effect of pure seed free from disease was clearly shown on farm 13 in 1928. One field of potatoes of home-grown stock yielded 6,500 pounds per acre, while certified seed free from disease yielded 10,500 pounds per acre.

It is within the power of every farmer to secure pure, clean seed, free from disease, for planting. The difference between profit and loss per acre may be due entirely to seed used. Inasmuch as seed is one of the important factors affecting yield, serious attention

The harrow aids in making a fine seedbed.

should be given in selecting the proper varieties which are true to type and free from disease.

Cultural Practice and Timeliness of Operations

Some farmers have their machinery ready for the field with all repairs and adjustments made so there will be no delay with the farm work. Some watch every crop and do their work when the most can be accomplished with the least effort. One case not included in these records, but on a neighboring farm, shows the difference between men.

In the fall of 1925 when potato prices were high and going higher, this farmer neglected potato digging for a week while he went on a hunting and fishing expedition. Then the heavy freeze came and he lost much of his crop. Other men were using two potato diggers to harvest their crop at a price seldom secured.

Other examples of doing work when it counts are: Planting beets early; cultivating when weeds are small; irrigating to keep crops growing at their maximum.

Productive Capacity of the Soil

Farmers who use manure, rotate their crops and make every effort to improve their land, such as leveling for better use of water, draining low spots or filling them in, find that their crop yields tend to improve.

With few exceptions the soil in this region is fertile and adapted to producing good crops. Yet the yields secured today are to a large degree due to the methods of handling the soil to build up

its content of organic matter and to make it more responsive to irrigation.

Of the uncontrollable factors little need be said. The weather comes and goes. Hail hits or misses the individual farm; frost kills the crops; rain delays spring work; prices rise and fall. Yet even here there is a chance for reducing the severity of these adverse conditions. Crops can be selected that are resistant to hail, or that mature early and avoid frost. Tractors can be used day and night to offset a late wet spring.

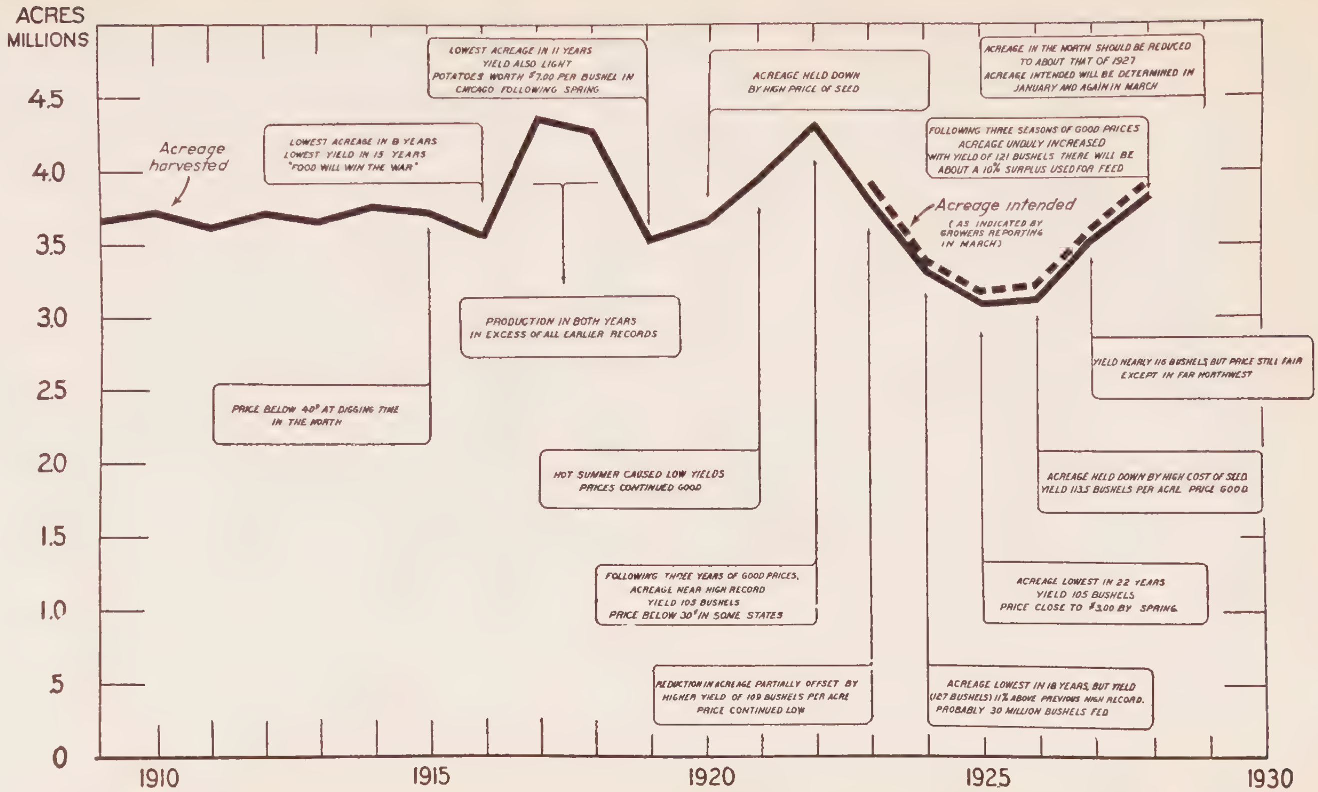
Prices are a problem and a study in themselves. Space does not permit a thoro analysis of this factor, yet it outweighs all others in its direct bearing on profit or loss. Several things should be studied closely by the individual farmer. First, what is the trend of prices. The chart of potato prices shows how they have fluctuated during the period of this study. First low, then high, it may be taken for granted that prices seldom remain the same. They are either getting better or worse. Hence the need for study to see what way they are headed and to find if there is anything that will change their direction. Government reports are the best guide for such a study.

Next is the question of foreign competition. Here the individual farmer is largely helpless unless he has political power sufficient to cause a change in the tariff to protect him, as is necessary with sugar beets. Failing in this move, the only recourse to meet foreign competition is to adapt and change the crops and methods of farming.

But above all other things in its importance in connection with price is the problem of when to sell. **Farmers should learn to sell on a rising market.** What do they actually do? Try to hold for the top price so they will make every possible profit! How does it usually work out? They never know when the top is reached. The price begins to fall. Then panic comes and they dump their crops, thus forcing prices farther down and resulting in more panic. Many instances of this could be cited from these records, especially with potatoes.

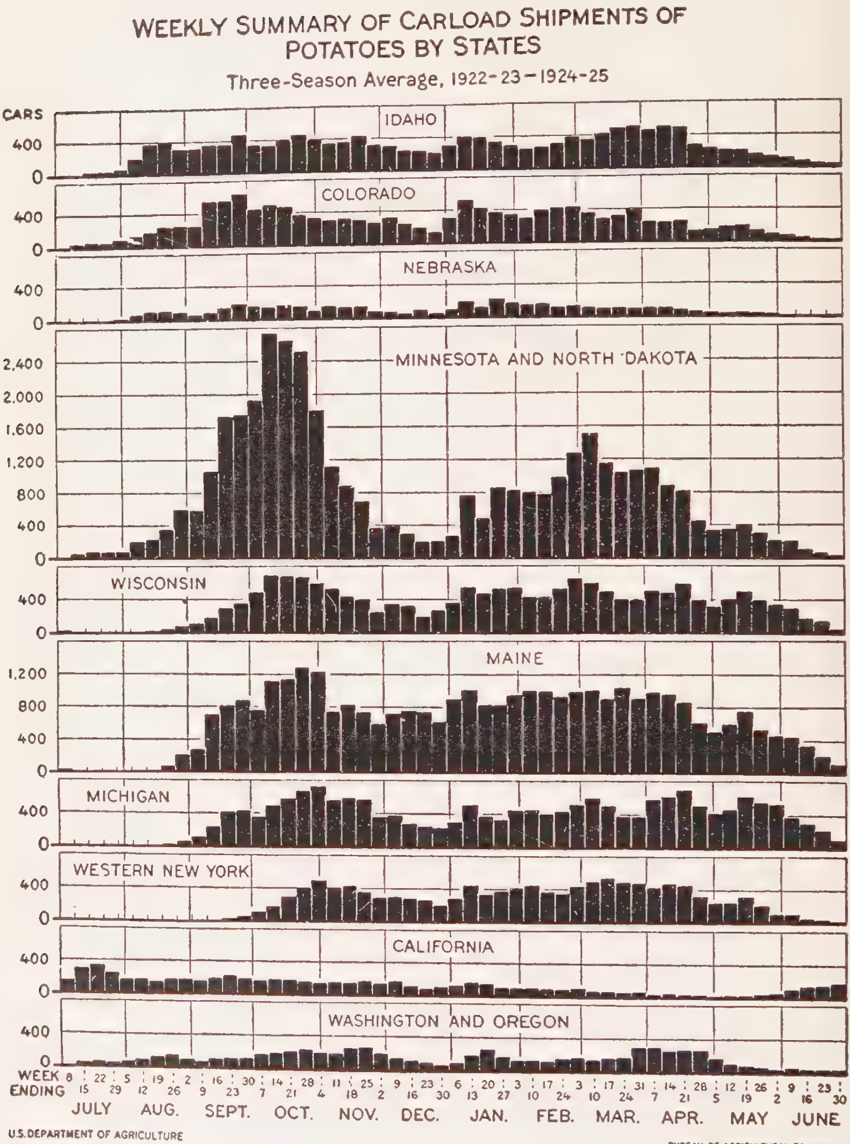
To sum up the problems of price: It would appear the part of wisdom to decide upon the rotation and crops that are adapted to one's location and soil, then keep to this plan over a period of years. If some great change in prices seems unavoidable, it might be advisable to make some modifications in acreage to result in an increased acreage when prices are high or a reduced acreage when prices are low. That is a hard thing to do. Few men can do it. Most are better off to ignore cycles of prices and grow the crop every year, or not at all.

FACTORS AFFECTING POTATO ACREAGE IN THE UNITED STATES



U. S. Department of Agriculture

Bureau of Agricultural Economics.



Colorado competes with other important states in the time of marketing potatoes.

Conclusion

The value of such data as are found in this bulletin is in aiding in individual farm operator in attempting to become more familiar with his own business enterprise.

The hours of man and horse labor can be used in planning the farm program. It has been pointed out that labor requirements vary between farms and between years. Reasons have been given for such variation, as to methods employed. Low labor requirements are generally associated with managerial ability of the farmer, able and skillful employees, large-sized units both in machinery and power units, and a tentative but carefully laid out farm program.

Any individual farmer applying these results should make allowance for conditions which exist under his particular environment different from those included in this study. He should also make allowance for his inability to use any of the methods of labor economy employed by others. After having made due allowance for non-similar conditions, the farmer may use these facts presented in this bulletin in determining his labor program and his cropping system. His object should be to so combine the crop and livestock enterprises as to make full utilization of his own labor and a reasonable amount of hired labor. The planning of a labor program will help to distribute the labor evenly thruout the year, avoiding peak loads and thereby high-priced labor. Doing those operations on crops and livestock which are pertinent to increased yields or economy of production should be the guide in choosing what to do and when to do it.

In other words, a seasonal distribution of labor should be the aim of all producers. How to secure a well-distributed labor program is partly determined by the crops that are included in the rotation and the sequence in which they follow each other. In choosing crops to be included one must determine what proportion of the farm should be included in row crops, in non-cultivated crops and in feed crops and cash crops.

This problem becomes interrelated then with what livestock program to follow consistently. How much livestock to keep and what kinds must be determined. A proper balance of crops will reduce the work stock to a minimum and at the same time result in a maximum net income.

Day to day planning of labor becomes necessary after laying out the whole labor and enterprise schemes. Some tasks must be performed every day, others may be shifted to periods when the work is not so pressing. Here again a knowledge of sequence of crops work is pertinent to economical planning. Weather may

interfere and then it becomes necessary to choose the crops which will return the greatest income for any given operation.

Relative labor requirements and relative expenses of production are invaluable to an enterprising farmer who desires to secure a comparative advantage over other producers.

The time is here when each and every producer must realize that those who are dominated by economic motives are those who will attempt to seek the largest net return from their business. Every man has under his control such things as the securing of the best seed, proper rotation of crops, use of farm manure, proper irrigation, work done at the right time. The old adage, "the eye of the master fattens the cattle," is equally true in the case of crops. The eye of the master does raise better crops at lower costs.

What hope do these records offer to the man who has been unsuccessful in past years? Can these records help him? Yes and no. No, if he cares not how things are done. Yes, if he is seeking for ways to increase his income. Why were his yields low? Why were his costs high? Why did he waste so large a percentage of his crop? Why did his alfalfa seeding fail? Are there things which he has left undone? If so, the fact that others in the same region have found a way to do better than he means that, within reason, possibly he, too, can change for the better.

What farming in the future needs more than all else is an alert, keen, businesslike supervision by the men on the job. A willingness to learn by experience! A willingness to exchange views, to seek ever for better methods!

Is it true that we irrigate our potatoes too late in the fall, thus injuring their quality? Then there is something to think about. Is it true that we have assumed that alfalfa seed from anywhere will grow under any kind of care? Then here is a chance to improve our stand and our yields. Is it true that we have overlooked the possibilities of permanent pastures? Then here is a way to get returns from our land with less expense.

The value of these cost figures is not so much a matter of their accuracy or their permanency as it is a matter of challenge to our ways of farming. If they do no more than cause us to search our own methods and seek for better ways, they have done their part toward improving the farming situation.

At all events they represent a starting point. One thing is sure, they are based on detailed records, kept as carefully as possible by men in sympathy with the study of farming, checked and calculated by men seeking knowledge of better practices and lower costs. They should stimulate further study by each individual farmer. They should be used as a guide and a starting point by one studying his own business.

Bulletin 354 January, 1930

SOME FACTORS RELATING TO THE
FEEDING HABITS OF GRASSHOPPERS

By George S. Langford

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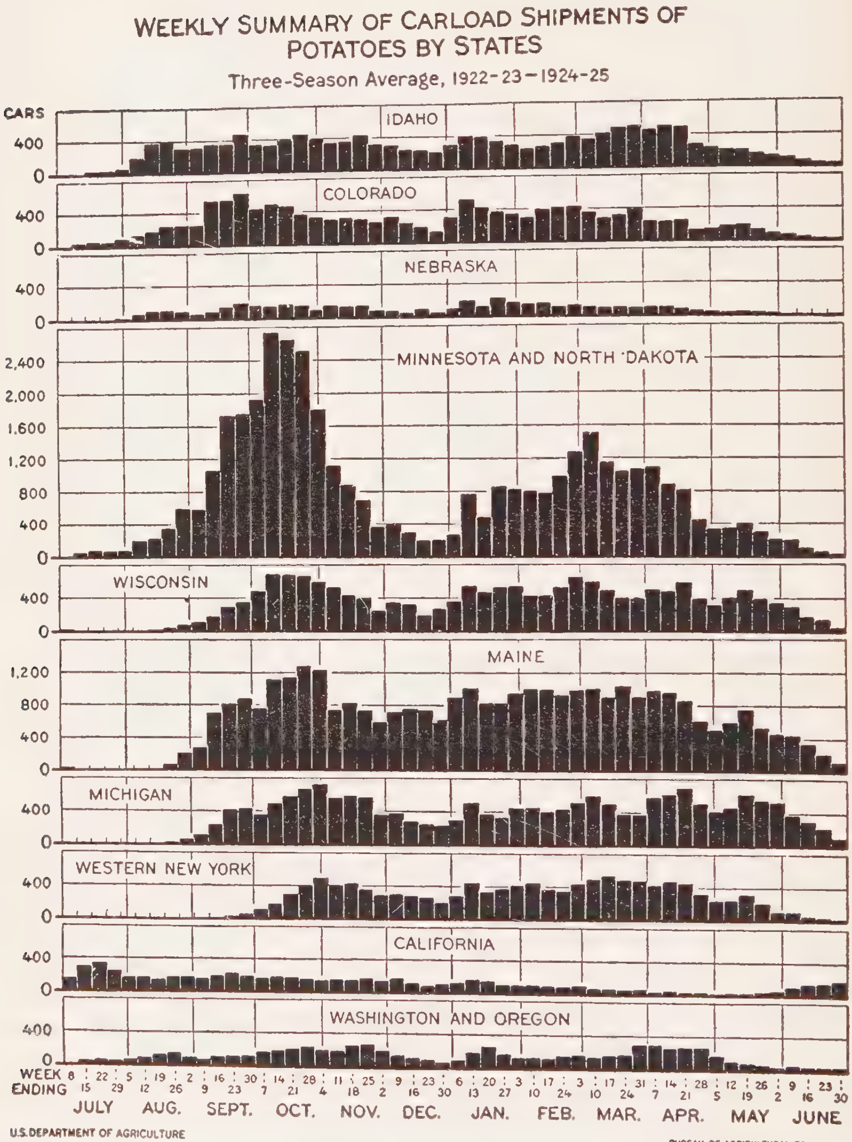

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SOME FACTORS RELATING TO THE

FEEDING HABITS OF GRASSHOPPERS

WITH SPECIAL REFERENCE TO

MELANOPLUS BIVITTATUS

By George S. Langford

These studies were made for the purpose of determining the effect of such factors as temperature, light, darkness and food plant upon grasshoppers, and their relation to control.

An intimate study of individual grasshoppers thru their life histories shows that temperature is apparently one of the most important factors regulating their rate of growth and daily activities, particularly the amount of food consumed daily. Such factors as light, darkness and the kind of food eaten appear to have little or no influence on the rate of development. The kind of food eaten determines the volume eaten and the number of times feeding occurs.

Normal activities occur between temperatures of 68 to 100 degrees F. A range of from 98 to 100 degrees in temperature appears to be the optimum. Grasshoppers react positively to this temperature range, and if maintained in it they will develop more rapidly and consume larger amounts of food than if maintained at a lower constant temperature. Temperatures above 105 degrees F. produce noticeable abnormal activities. Prolonged exposure to a temperature of 120 degrees F. will produce death. The physiological mechanism of grasshoppers is such as to carry them over relatively long periods without food or water when the temperature is low. At a low constant temperature of approximately 38 degrees F. they can live without food or water for a period of 192 to 240 or more hours, while at a constant temperature of 95 degrees F. death occurs in from 48 to 72 hours. By regulating the temperature under which a grasshopper is developing, the time required from the first instar to the adult may be varied from 30 days to more than 4 months. Grasshoppers moult from 5 to 7 times. Grasshoppers moulting the greatest number of times appear to be largest in size.

Grasshoppers apparently do not lay eggs when the air temperature is below 69 degrees F. or the soil temperature 65 degrees F. Egg laying has been observed to take place under rather variable moisture conditions, eggs being deposited in sandy soil when the soil moisture content varied from 9.77 to 20 percent.

When a temperature of 68 to 100 degrees F. is obtainable, feeding normally occurs thruout the entire day. The heaviest

feeding period occurs during the warmer portions of the day. This is indicated by the number of individuals feeding, the amount of food eaten, and the number of times feeding occurs. Normally, feeding does not cease during the hot portion of the day regardless of the temperature recorded by the weather-bureau method. If favorable, grasshoppers react to the environment where the temperature is at the optimum or nearly so and continue to feed.

The amount of food consumed daily per individual varies with the daily temperature. For lettuce it may vary from nothing at 55 degrees F. to 11.3 square inches for a 24-hour day at 95 degrees F. First instar nymphs eat from .02 to .14 square inches of lettuce each day depending upon the temperature and age of the grasshopper. As moulting takes place the amount of food eaten increases rapidly, in fact it almost doubles with each instar. Immature forms eat much less than adults. Adult females eat from 2 to 7.5 square inches of lettuce during a 12-hour day and on an average of 2.5 times more than males of the same species, under the same temperature conditions. Adult females eat daily more than 100 times as much as first-instar nymphs. There is considerable variation in the daily feeding activities. Individuals of the same brood vary in the amount eaten, also the same indviduals under apparently the same conditions vary from day to day. Both nymphs and adults in 24 hours eat 56.7 to 74.6 percent more food than in 12 hours if kept at a constant temperature of 95 degrees F. Age apparently does not affect the amount eaten by adult grasshoppers as long as they are active and are producing eggs or sperms.

When feeding upon different food plants, grasshoppers show an enormous difference in the amount they eat. This is true for all stages in their development. Normally they eat from 3 to 4 times as much lettuce as alfalfa per day. This variation may be accounted for to a certain extent by the dry-weight content of the plants. However, to account for the entire amount, it would appear that a knowledge of the exact extent to which a grasshopper is capable of digesting the nutrients of each material utilized, seems necessary.

Grasshoppers, normally, do not feed the day before moulting nor for several hours after.

The number of hourly periods in which a grasshopper eats during a day are few. The type of food determines this to a large extent. Individuals feeding upon lettuce average 5.7 feeding periods while those feeding on alfalfa average 3.2 for a 12-hour day.

Each feeding period is comparatively short. Sixteen minutes was the average for one period. Grasshoppers feeding on lettuce probably do not use over 3 hours a day, while those feeding on alfalfa probably do not use over 2 hours.

This kind of food plant apparently has no effect on the rate of development. Comparative studies show that grasshoppers reared entirely on lettuce completed 5 instars in approximately the same period of time as those reared on alfalfa.

Comparative studies indicate that light days of different lengths do not affect the rate of development as long as the temperature is constant.

Grasshoppers are capable of eating, growing and moulting in total darkness. When maintained under the same temperature conditions, development appeared to be as rapid in complete darkness as under normal day and night-light conditions.

The above-mentioned factors are closely associated with the abundance of grasshoppers in their normal environment from year to year and they also have a direct bearing upon control.

INTRODUCTION

Grasshoppers are world wide in their distribution. Evidence indicates that they have been a pest to agriculture since man began to till the soil. The writings of the Egyptians, Greeks and Ancient Hebrews contain references to these insects as pests to agriculture.

In Colorado conditions are usually favorable for grasshopper development, therefore the state always suffers more or less injury each season. It can be conservatively stated that grasshoppers cause greater losses to crops than any one other insect in the state.

Riley (60) states that since the year 1333, outbreaks have been recorded regularly. The literature is full of references concerning control. The following are a few of the control methods employed or recommended in the past: Prayer, making noises, using of soldiers, offers of bounties, poisonous plants, fire, crushing, collecting, spraying with poisons, destruction of eggs, use of turkeys, barriers, poisonous dusts and baits.

In America poisonous baits have proved the most successful type of control. However, there is a great difference in opinion as to the correct time for their application. Since the efficiency of the baits depends to a large extent on the time of application, it is of the utmost importance to know those factors which regulate the habits of grasshoppers, especially the feeding habits, in order that the use of baits may be effectively employed.

Figure 1.—Type of cage used in grasshopper experiments. (About one-half natural size.) This type of cage was used almost exclusively in studying individual hourly records A and B indicate method of feeding plants, with large leaves, as lettuce. The stems of the plants were kept in water.

The purpose of this investigation was to study the effects of such factors as temperature, light, darkness and food plant upon the development and general activities of grasshoppers. Special emphasis was placed on the factors which regulate feeding, the amount of food eaten, and the time of feeding for conditions in Colorado and at the same time to test the correctness of observations made by other workers.

The data thus far obtained and conclusions reached are believed to be of such a nature as to justify a report. Observations

were made over a 4-year period, 1924-1927, at Fort Collins, Colorado.

The author is indebted to Dr. C. P. Gillette and Mr. Geo. M. List for their encouragement, valuable suggestions and criticisms, and to J. L. Hoerner and S. C. McCampbell for valuable aid on many occasions.

METHODS OF EXPERIMENTATION

The present studies are based primarily on laboratory observations and supplemented with field observations, the individual grasshopper being taken as the unit of study. The reactions of the individual to various stimuli is the basis on which conclusions have been drawn.

A greenhouse and insectary were used as a laboratory for rearing except in those cases where the temperature cabinet was employed. The environmental data recorded are those in the immediate vicinity of the grasshopper. In the case of temperature, the readings were made inside the cage containing the grasshopper.

Fig. 2.—One type of cage used in the experimental work. (About one-half natural size.) Plant leaves are kept turgid by maintaining them in water as illustrated in Fig. 3.

Only one grasshopper was maintained in a cage. Cages of two different designs as illustrated in Figures 1 and 2 were employed. The cage illustrated in Figure 1 was a glass cylinder 8 inches in length and 2 and one-quarter inches in diameter, and was used for most of the work. The cage illustrated in Figure 2 was made by inverting a 4-inch flower pot over a bottle containing water. A cylindrical copper screen 8 inches in length and about 4 inches in diameter was fitted around the rim of the pot. The intervening space between the rim and bottom

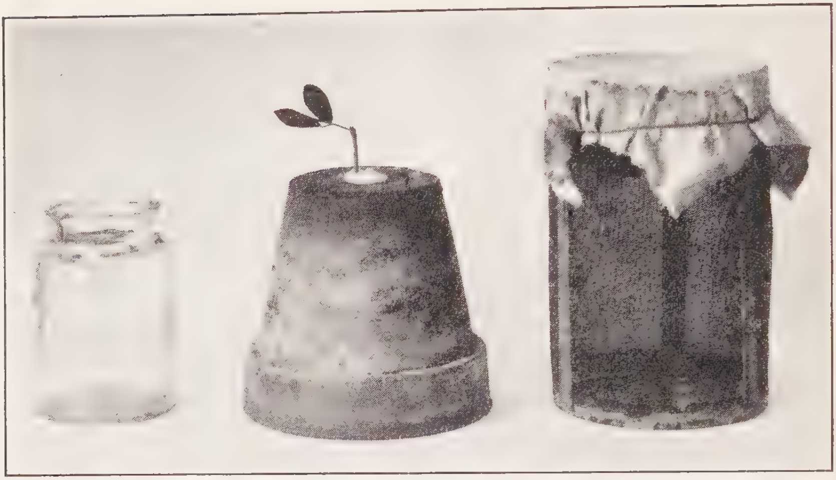

Fig. 2-A.—Showing unassembled parts of grasshopper cage illustrated in Fig. 2.

of the pot was filled with sand. The food plant was placed thru the drain in the bottom of the inverted pot, with its stem extended into the bottle of water beneath, and held firm by a cotton plug.

In the feeding investigations the grasshoppers were fed hourly on fresh leaves, the stems of which were kept in water. When plants having large or delicate leaves were fed, the leaves used were placed in a heavy cardboard or celluloid holder as illustrated in Figure 1. The surface area of the leaves was recorded before and after being fed, by a photo-print method. The difference between the surface areas calculated by the use of a planimeter was the amount eaten. To obtain an accurate reading of the amount eaten by the small nymphs, it was often necessary to enlarge the print by projecting it upon a screen placed upon a table.

The photo-prints were made by using either blueprint or Van-Dyke paper. The Van-Dyke paper has an advantage over the blueprint paper in that it can be readily photographed without being traced; also one can make blueprints from it. Figures 3 and 4 illustrate the method of printing and results obtained. Figure 5 represents the method of recording data.

Several methods were considered for recording results. The above was selected because of its simplicity and because it permitted the study of a larger number of individuals with the labor available. It also permitted a study of the actual leaf surface eaten. This, the writer felt, was significant, as grasshop-

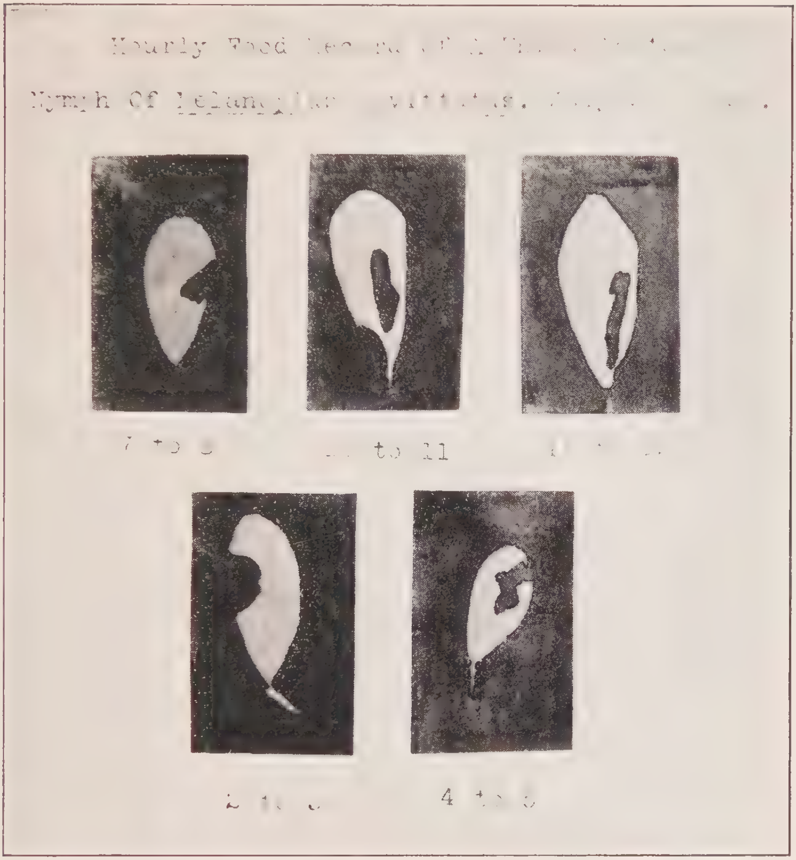

Fig. 3.—Photograph showing photo-print method of recording the amount of food eaten hourly by a grasshopper on alfalfa. (Slightly reduced.)

pers vary in the amount of food they eat when feeding on different plants.

The method has a distinct advantage in that large amounts of work can be done during the months when the insects are available and the data may be worked at another time. There is a disadvantage in the method in that it is subject to some experimental error. Plants growing under different moisture conditions will vary in the amount of water they contain in their tissues, also in the thickness of their leaves. This, of course, would cause some variation in determining the dry weight from figures obtained by the above method.

Most of the plants used in the experiments were obtained from plants grown under normal cultural practices. The alfalfa

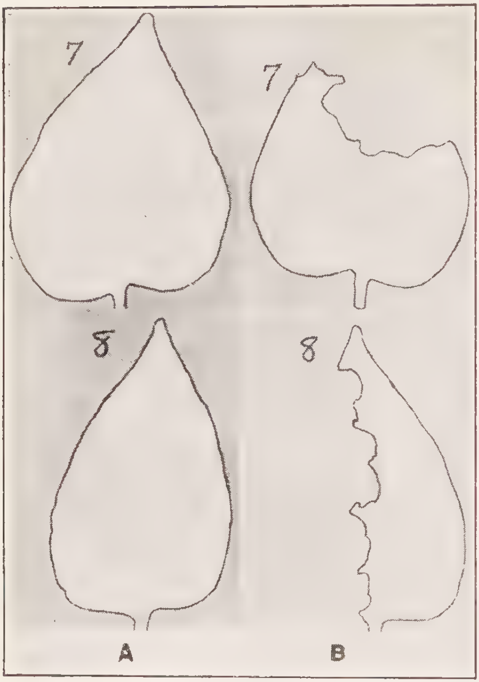

Fig. 4.—Photograph showing results of grasshopper feeding as recorded by photoprints. A, before feeding; B after feeding. (Slightly reduced.)

used was obtained, for the most part, from fields under normal irrigation conditions. All the grasshoppers used in the experiments were hatched from eggs collected in the field during early spring or from females kept in the laboratory. The conditions of insect growth were varied by the use of greenhouse, insectary and constant-temperature chambers.

Effects of Temperature on Activities

Grasshoppers belong to that group of animals that do not have a heat-regulating mechanism, therefore they must depend upon the temperature of their surroundings. The temperatures of their environment in which activity takes place are variable and may be subject to sudden changes. In studying the habits of grasshoppers it is quite important to know the temperatures in which they are active and function normally, also the optimum temperature.

Parker (54), working on *Camnula pellucida*, found that when the air temperature goes above 60 degrees F. some crawl from their hiding places and at 65 degrees F. nearly all will be in the open. After the air temperature extends above 68 degrees F. they begin to move about and enter upon the normal activities of the day. First and second instar nymphs have for their optimum a temperature range of 98 to 100 degrees F. As a rule, feeding stops at 68 degrees F. as the minimum. For the maximum, feeding sometimes continued in temperature cabinets until a temperature of 113 degrees F. was reached.

The writer, working with *Melanoplus bivittatus*, found this species reacted very similarly and within approximately the

Daily Food Record Second Instar *Melanoplus bivittatus*
Showing Hours of Feeding and Area of Leaf Surface
Consumed During the Day. May 25, 1927.
Food Plant - Lettuce

Mean hourly Temp.	65.5	73	79.5	83	83	84.5	86	86.5	85	81	77	74.5	Total Area Food Consumed In Square Inches
Temp. F.	61-[illegible]	70-[illegible]	76-[illegible]	83-83	[illegible]-83	83-86	86-86	86-[illegible]	87-83	83-79	79-75	75-74	
Hour	7-8	8-9	9-10	10-11	11-12	12-1	1-2	2-3	3-4	4-5	5-6	6-7	
Indiv. No.					Area Food Plant Consumed								
1			[illegible]				.040			.040	.020	.010	.145
2					.01[illegible]		[illegible]	.015		.015	.01[illegible]		[illegible]
3	.030			.025	.010	.015	.005	.005		.015	.030		.135
4			.010	.010		.015	.020	.001			.015		.071
5	.015			.005			.040	.005	.010		.030		.105
6	[illegible]		[illegible]	.020		.020	.010	[illegible]	.005		[illegible]		.102
7	[illegible]			[illegible]		.015	[illegible]	.040		.010	.020		.135
8	.002		[illegible]	.015	.010	.010		.020	.01[illegible]		[illegible]		[illegible]
9	.010	.005	.005	.015	.010	.020	.020	.015	.007	.005	.012		.124
10	[illegible]				.030		.015	[illegible]			[illegible]		[illegible]
11		.015	.005		.010	.025	.010	[illegible]	.017			.005	.092
12	.020				.020			.030			[illegible]	.005	.090
Total Area Eaten	.137	[illegible]	[illegible]	.110	[illegible]	.120	[illegible]	.151	.049	.085	.217	.020	1.271
No. Feeding	[illegible]	[illegible]	6	7	7	7	[illegible]	10	5	5	11	3	12
% Feeding	66	16	50	58	58	58	83	83	41	41	91	25	100

Fig. 5.—Photograph illustrating the method of recording the amount eaten by individual grasshoppers each hour.

same temperature limits as Parker found for *Camnula pellucida*. However, it was found that in a study of individuals of this species, in cages, that the range of activities was apparently slightly greater than that reported for *Camnula pellucida*.

Using the same type of apparatus described by Parker (54) the optimum temperature was found to be from 98 to 100 degrees F., the minimum effective to be from 65 to 68 degrees F. for normal activities, altho feeding on many occasions was observed to take place at much lower temperatures. Immature grasshoppers occasionally feed when the temperature does not exceed 58 degrees F. Adults were never observed feeding at temperatures below 60 degrees F. Table 1 includes records of grasshoppers feeding at low temperatures.

Temperatures above 104 to 105 degrees F. produced abnormal activities while temperatures from 110 to 115 degrees F. caused the grasshoppers to become very nervous. Increasing the temperature caused increased activity until the animals were overcome. On several occasions feeding was observed when the temperature was 112 and 115 degrees F. On one occasion an adult male was observed to feed upon a four o'clock leaf for a brief time when the temperature was 122 degrees F. Prolonged exposure at this temperature will cause death.

The above results show that *Melanoplus bivittatus* reacts normally between the temperatures of 68 to 100 degrees F. and that 98 to 100 degrees F. is the optimum.

Preliminary studies indicate that *Melanoplus bivittatus* can withstand higher temperatures than *M. Femur-rubrum.* Five experiments, the results of which are recorded in Table 2, all furnish evidence of this.

Individuals of the same species vary considerably in their ability to withstand heat. It is not uncommon for a few resistant individuals to be active when a vast majority of the individuals have succumbed.

Simple starvation tests indicate that temperature has an important bearing on the ability of grasshoppers to withstand starvation. Physiologically they appear to be so adjusted as to be able to survive long periods without food when the temperature is low, but very short periods when the temperature is high.

Table 1.—Minimum Temperatures at which Grasshoppers were Recorded Feeding.

Temp. range Fahr.	Hour a. m.	Number observed	Number feeding	Instar	Date
52—58	8—9	8	2	1	5-18-26
54—58	8—9	13	2	2	5-25-27
55—58	8—9	8	0	3	6-3-26
55—58	8—9	2	0	4	6-3-26
55—58	8—9	7	1	1	6-3-26
55—58	8—9	3	0	2	6-3-26
57—61	8—9	4	2	3	5-27-26
57—61	8—9	3	1	4	5-27-26
57—61	8—9	5	4	1	5-27-26
57—61	8—9	5	0	2	5-27-26
57—61	6—7	11	4	3	6-2-27
58—60	9—10	4	2	1	5-28-26
53—60	9—10	5	0	2	5-28-26
58—60	9—10	4	1	3	5-28-26
58—60	9—10	3	2	4	5-28-26
59—61	8—9	5	1	2	6-3-26
59—61	8—9	5	1	3	6-3-26
59—61	8—9	4	2	4	6-3-26
59—61	8—9	10	0	1	6-3-26
61—63	8—9	4	0	3	5-26-26
61—63	8—9	3	1	4	5-26-26
61—63	8—9	5	3	1	5-26-26
61—63	8—9	5	1	2	5-26-26
53—62	8—9	12	8	2	5-23-27
60—63	7—8	9	6	3	6-1-27
60—63	7—8	13	6	3	6-1-27
58—64	7—8	9	2	4	6-17-27
58—64	7—8	10	4	4	6-17-27
58—64	7—8	11	7	4	6-17-27
58—64	7—8	5	3	5	6-30-27
61—63	9—10	25	13	Adult F.	10-29-26
61—63	9—10	14	6	Adult M.	10-29-26

Table 2.—Preliminary Comparison of Effect of High Temperature on *Melanoplus bivittatus* and *Melanoplus femur-rubrum.*

Exp.	Date 1927	Species	Temp. Fahr.	Number minutes exposed	Percentage dead after 24 hours
1	9-12	*M. femur-rubrum*	130	40	65
	9-12	*M. bivittatus*	130	40	0
2	9-13	*M. femur-rubrum*	130—145	40	100
	9-13	*M. bivittatus*	130—145	40	66
3	9-13	*M. femur-rubrum*	140—150	35	100
	9-13	*M. bivittatus*	140—150	35	66
4	9-13	*M. femur-rubrum*	160	7	100
	9-13	*M. bivittatus*	160	7	50
5	9-13	*M. femur-rubrum*	140	?	62
	9-13	*M. bivittatus*	140	?	17
	9-13	*M. differentialis*	140	?	84

The grasshoppers were placed in cages as illustrated in Figure 1 and then placed in the temperature cabinet and allowed to remain for the length of time indicated. Therefore these figures do not represent the actual time the animals were exposed to the stated temperatures.

Montana entomologists (55) have shown that the amount of food grasshoppers eat depends upon the temperature. The writer's work discussed elsewhere in this paper corroborates this. Apparently more food is required to care for the increased metabolic activities under high temperature conditions. Bodine (6) has shown that there is a correlation between water content and temperature. He pointed out that in passing from low to high temperatures the water content of grasshoppers increases. Also that starvation reduces the water content. Thus it would seem logical that if these animals were exposed to high temperatures it would require more food to maintain the necessary water content for normal metabolic activities.

The summarized results of the starvation tests are as follows: When *M. femur-rubrum* and *M. differentialis* were exposed to a constant temperature of 95 degrees F. for 48 hours there was an average mortality of 70 percent, while the same species exposed to a temperature of 69 degrees F. were all alive at the end of 48 hours. At 55 degrees F. and after starvation for 120 hours all grasshoppers were alive. At 38 degrees F. 100 percent were alive after 192 hours, and 40 percent showed signs of life after 312 hours.

Life-History Studies and Temperature

In order to obtain grasshoppers of given stages and of known ages, an extensive series of life-history studies was made. Detailed studies on the life histories of the following species were made for comparison: *M. bivittatus, M. differentialis, M. femur-rubrum* and *Chortophaga viridifaciatus.* Notes on the temperature and daily rate of development were recorded.

Temperature has a very important bearing on the rate of development. Parker (8) and Fry (29) have made and reported extensive studies on the effect of temperature on the rate of development. Since the writer's observations agree in essentials with the published work of these men, the details are omitted. Without doubt temperature is an important factor in development. As the Montana entomologists (55) have stated, it is possibly one of the factors affecting grasshopper outbreaks. The time of feeding, the amount of food eaten and the rate of development in the laboratory can be regulated by it.

By regulating the temperature, the life history from the hatched egg to the adult stage may be completed in less than 30 days, or may require more than 4 months. The period between moults may vary from 3 to 30 days depending on the temperature. On one occasion a newly hatched nymph kept at a relatively low temperature lived 108 days without moulting.

Grasshoppers moult from 5 to 7 times. The factor which causes this variation was not determined. In a series that developed in the greenhouse from March 5 to about June 10 under comparatively low temperatures practically all individuals moulted 6 or 7 times.

Another series developing from May 10 to about July 15 and subject to higher temperatures completed growth with but few exceptions in 5 moults. This would indicate that temperature is a factor. However, another series of *M. differentialis* growing under a constant temperature of 95 degrees F., all moulted 6 or 7 times. This would indicate that some other factor might be causing some of the variation. Indications are that the grasshoppers having the greater number of moults are the largest. This has always been the case with those studied by the writer.

Somes (74) states that there are 2 broods of *Chortophaga viridifaciatus* in Minnesota. Blatchley (1920) in his treatise on *Orthoptera* of N. E. North America, states that there is 1 generation in Indiana. Very careful rearings show that there is 1 generation in the vicinity of Fort Collins, Colorado. The adults are present from late April until fall. Egg deposition begins the latter part of May or early June and may continue for several weeks. Hatching may begin the latter part of June and continue for several weeks. Most of the nymphs begin hibernating in the third or fourth instar.

In the vicinity of Fort Collins eggs of *M. bivittatus* have been observed hatching as early as April 20. The majority of the eggs hatch during May and early June. Adults were found in the field on June 20 in 1926. Most of the nymphs mature dur-

ing July. Development takes place over a period of several weeks. Nymphs can often be found in the field from about April 20 to September 1.

OBSERVATIONS ON EGG DEPOSITION *Melanoplus bivittatus*

No extensive observations were made of the egg-laying habits. However, during the summer and fall months of 1925 and 1926 a series of observations were made on *M. bivittatus* in the vicinity of Fort Collins. Special emphasis was placed upon the egg-deposition period, number of eggs laid and the time and conditions required for deposition.

It was found that many individuals of this species are copulating freely from the first week to the middle of July. On July 13, 1925, a number of females were examined that contained well-developed eggs within the abdomen. By August 14 a large percentage of females had their abdomens distended with eggs. Egg deposition may take place from the middle of August until the middle of October. On October 17, 1926, females were observed laying during the middle of the day.

During the summer and fall months females were collected and caged in order that information might be obtained concerning the number of eggs deposited and the time required. During this same period females were dissected and counts made of the number of eggs in their ovaries.

From the egg counts made there seems to be a wide variation in the number of eggs in an egg pod. From a total of 42 pods examined the number of eggs per pod varied from 15 to 135 with an average of 59.8. In the counts made from 30 dissected gravid females the number of apparently fully developed eggs in the ovaries varied from 26 to 83 with an average of 68.

Observations were obtained from 24 individuals on the time required to deposit their eggs. The deposition period recorded was from the time the ovipositor began to be inserted in the ground until it was withdrawn. The soil temperature was recorded by placing a thermometer about 2 inches from the grasshopper and 1½ inches below the surface. All observations were made on caged grasshoppers. The minimum time required was 1 hour and 11 minutes, the maximum, 3 hours and 58 minutes, and the average was 2 hours and 3 minutes.

Only in one instance was egg laying observed when the temperature was below 70 degrees F. In that case the air temperature was 69 degrees F. On several occasions eggs were deposited when the soil temperature was 65 degrees F.

Eggs were deposited in a sandy soil with a moisture content as low as 9.77 percent and as high as 20 percent water.

Table 3.—Egg-laying Records—*Melanoplus bivittatus*, Fort Collins, Colorado, 1926.

Grass-hopper No.	Date laid	Hour laying started	Hour finished	Time required for depositing eggs	Number Eggs in pod	Air temp.	Soil temp.	Soil moisture content
2	10-22	2:43 p. m.	4:59 p. m.	2 Hrs. 16 Min.	33	69 F.	65 F.	
7	10-26	11:50 a. m.	3:11 p. m.	3 Hrs. 21 Min.	65	77 F.	65 F.	10.01 percent
8	10-26	12:55 p. m.	3:11 p. m.	2 Hrs. 16 Min.	36	78 F.	69 F.	
11	10-25	2:12 p. m.	5:45 p. m.	3 Hrs. 33 Min.	54	76 F.	69 F.	9.77 percent
13	10-26	12:00 noon	3:17 p. m.	3 Hrs. 17 Min.		77 F.	68 F.	
17	10-27	1:00 p. m.	3:51 p. m.	2 Hrs. 51 Min.		78 F.	65 F.	
18	10-26	1:00 p. m.	4:38 p. m.	3 Hrs. 38 Min.	135	78 F.	69 F.	
30	10-25	11:54 a. m.	3:30 p. m	3 Hrs. 36 Min.	80	77 F.	67 F.	13.16 percent
22	10-25	11:33 a. m.	3:17 p. m.	3 Hrs. 44 Min.	81	78 F.	67 F.	13.16 percent
32	10-25	10:00 a. m.	11:11 a. m.	1 Hr. 11 Min.	69	80 F.	68 F.	9.78 percent
40	10-25	11:20 a. m.	1:06 p. m.	1 Hr. 46 Min.	51	75 F.	65 F.	20.00 percent
41	10-25	2:22 p. m.	5:00 p. m.	2 Hrs. 38 Min.	45	76 F.	67 F.	13.57 percent
9	10-22	12:00 noon	2:55 p. m.	2 Hrs. 55 Min.	90	70 F.	66 F.	
15	10-25	2:12 p. m.	5:00 p. m.	2 Hrs. 48 Min.	73	75 F.	69 F.	10.01 percent
14	10-25	11:54 a. m.	3:52 p. m.	3 Hrs. 58 Min.	15	76 F.	68 F.	
27	11-4	11:45 a. m.	2:36 p. m.	2 Hrs. 51 Min.		72 F.	68 F.	
26	11-5	2:06 p. m.	4:00 p. m.	1 Hr. 54 Min.		72 F.	69 F.	
46	11-4	1:20 p. m.	3:54 p. m.	2 Hrs. 34 Min.		82 F.	68 F.	
47	11-3	1:50 p. m.	3:29 p. m.	1 Hr. 29 Min.	66	76 F.	69 F.	
19	11-4	2:00 p. m.	4:56 p. m.	2 Hrs. 56 Min.		75 F.	69 F.	
48	11-26	11:00 a. m.	12:55 p. m.	1 Hr. 55 Min.	52	76 F.	68 F.	
1	10-22	12:00 noon	3:58 p. m.	3 Hrs. 58 Min.		70 F.	66 F.	
10	10-21	1:05 p. m.	2:30 p. m.	1 Hr. 25 Min.		72 F.	66 F.	
12	10-22	12:00 ?	2:48 p. m.	2 Hrs. 48 Min.		70 F.		

Table 3 gives information concerning the egg deposition records.

Definite information on the number of egg pods a female of this species will lay was not obtained. However the writer obtained two pods of eggs from individuals and after death an examination showed them to contain well-developed eggs in their ovaries.

DAILY FEEDING ACTIVITIES

Investigators have made extensive studies to find the time of day that grasshoppers feed most on poisoned-bran mash. Practically all workers have concluded that temperature is a limiting factor but in general that the period of greatest feeding on poisoned-bran mash is during the morning hours after the temperature reaches 65 degrees F. or above, and continues until the temperature reaches 75 or 80 degrees F. This information has been obtained by a simple and effective method commonly termed the "pan method." Briefly, this method consists of placing fresh bait at hourly intervals on a series of pans, and then making counts each 10 minutes of the number of grasshoppers visiting and feeding at the pans. In literature there is but little information concerning the actual feeding activities of grasshoppers. Many farmers who poison and apparently a few scientists who have not worked with grasshoppers have come to believe that these insects feed heaviest during the morning hours when the temperature is between 75 and 80 degrees F.

The following experimental evidence will show why the "pan method" gives approximately a true measure to feeding on poisoned-bran mash, but does not show any relation to the feeding activities of a grasshopper during the entire day.

Temperatures recorded by the standard method employed by the weather bureau cannot be considered when reckoning with individual grasshoppers, since the temperature in the immediate proximity of the grasshopper must be used as a basis. Numerous observations have demonstrated that a variation of 70 to 80 degrees may be obtained at the same time within a given field. According to Hann's Handbook of Climatology, a difference as great as 128.30 degrees F. may exist, in high altitudes, between sun and shade temperature. Thus, within temperature ranges where activity is possible, grasshoppers have an opportunity to and do orient themselves so as to remain in or near their optimum by using grass, debris and other available materials. If such were not the case during an ordinary summer,

many grasshoppers in open fields would be destroyed from heat rigor.

Using an actual case recorded at Fort Collins, Colorado, June 30, 1926, the following temperature variations were recorded:

Hour	8	9	10	11	12	*1	2	3	4	5
Air Temperature	76	77.5	78	77	86	81	81	78	73	65
Temperature at soil surface in sun	95	100	114	103	107	102	92	89	76	64
Temperature at base of alfalfa in shade......	62	66	73	69	78	73	70	70	67.5	64
Temperature 21 inches above ground in sun	78.5	80	81.5	77	87.5	77	75.5	74	70.5	63
Temperature 8 inches above ground in alfalfa shade	69	69	79	76	87.5	77	72.5	73	69.5	64

*After 1 p. m., sky hazy to cloudy.

If we should select from the above data the temperatures at the soil surface, and then allow the grasshoppers to remain at or below their optimum, and from this construct a curve, it would show, during the day, 2 peaks when grasshoppers are most likely to be found on and feeding at the ground. This curve would rise rapidly during the morning until at 9:30 a. m., then it would fall and remain low for a period until 1:30 or 2:00 p. m. At this time it would again rise rapidly and remain high until 5:00 p. m., and again fall. This curve is very similar to one that would be obtained from using the "pan method" and represents the periods during the day when the grasshoppers are in contact with and feeding upon the poisoned-bran mash which is scattered upon the ground. Yet it cannot be relied upon to represent the actual feeding operations of grasshoppers. The "pan method" will always yield the above-mentioned type of curve and grasshoppers will feed heaviest on poisoned-bran mash during the above periods for several reasons.

1. In early morning during the "warming up" period grasshoppers always collect in the open and in places where they can obtain the maximum warmth from the sun. Here they will remain and feed until the temperature passes their optimum. The pans afford an ideal place for this. This is also a period when they are in contact with the poisoned-bran mash.

2. As soon as the temperature passes the optimum the grasshoppers move and adjust themselves to a more suitable temperature in the vegetation but continue to feed.

3. During the afternoon, as the temperature falls, the areas shaded by vegetation cool, so that the grasshoppers react again and are found in more open places having a temperature

nearer their optimum. The pans again afford an ideal place. This accounts for the afternoon peak.

In a laboratory study of *M. bivittatus*, in all stages of its development and feeding on both alfalfa and lettuce, it was found that this grasshopper begins feeding as soon as the temperature reaches 65 to 68 degrees F. and continues to feed during the entire day, the greatest amount of feeding usually taking place during that portion of the day when the mean hourly temperature is highest. Normally, this occurs during the middle of the day; however there may be some variation to this. The above results are indicated by the percentage of animals feeding; the number of hours in which feeding occurred and the amount of food eaten. Details of the summarized individual experiments are given in Table 5.

The summarized results which represent the feeding of a total of 123 grasshoppers on lettuce over a period of 11 days and a total of 146 grasshoppers on alfalfa over a period of 13 days, afford additional evidence for the above statements. The day was divided into 3 equal parts of 4 hours each and the results are based on the averages for each of these periods. The maximum variation in the numbers feeding on alfalfa was 4.1 percent between any of the periods. For those feeding on lettuce, the maximum variation was 4.9 percent. The variation in the number of hourly periods in which feeding occurred and the amount eaten was somewhat greater. The latter variation can be very closely associated with the fluctuation in temperature, which is to be expected since the grasshoppers eat more at high than low temperatures. Table 4 gives the results.

Table 5.—Showing the Distribution of the Daily Feeding Activities of *Melanoplus bivittatus*.

	Morning period 7 a. m.-11 a. m.		Noon period 11 a. m.-3 p. m.		Afternoon period 3 p. m.-7 p. m.	
	Alfalfa*	Lettuce**	Alfalfa*	Lettuce**	Alfalfa*	Lettuce**
Percentage Feeding	69.8	86.9	73.9	91.8	72.6	91.8
Number hourly periods in which feeding occurred ..	154	208	166	280	178	237
Amount eaten—square inches ..	23.5	9.3	25.7	16.9	27.8	11.6
Mean hourly temperature	69	70.3	79.8	82.8	74.5	76

*Nymphs and adults. Data based on averages from feeding records taken on 13 different days, using 146 individuals.

**Nymphs. Data based on averages from feeding records taken on 11 different days, using 123 individuals.

Table 5.—Daily Food Record *Melanoplus bivittatus* Based on Hourly Feeding Records—12-hour Day, Fort Collins, Colorado.
Food plant—Lettuce

		Morning period				Noon period				Afternoon period						
Exp.	Date	Percentage feeding	Number periods feeding occurred	Amount food consumed	Mean hourly temp.	Percentage feeding	Number periods feeding occurred	Amount food consumed	Mean hourly temp.	Percentage feeding	Number periods feeding occurred	Amount food consumed	Mean hourly temp.	Number of individuals	Range of temp. Fahr. from 7 a. m. to 7 p. m. Max.	Min.
	1926							First instar								
200	5-16	84	13	.116	70.5	69	13	.240	84.3	92	24	.353	78.2	13	87	55
300	5-17	100	33	.484	76	100	36	.443	84.8	100	28	.329	78.8	14	89	60
								Second instar								
300	5-23	83	19	.407	63.2	100	32	.746	81	100	22	.426	73.4	12	85	50
200	5-25	69	12	.260	68.8	100	32	.541	86.6	92	22	.284	78.4	13	89	51
300	5-25	91	23	.349	74.6	100	34	.551	85	100	24	.371	79.6	12	87	61
								Third instar								
200	6-1	84	29	1.208	72.6	100	34	2.017	85.2	100	29	1.461	74.4	13	87	57
300	6-2	90	19	.770	71.4	100	28	1.387	80	100	24	1.120	72	11	89	57
								Fourth instar								
200	6-17	90	17	1.755	69.6	80	22	2.640	80.4	70	15	1.710	76.6	10	83	58
300	6-17	100	24	1.635	69.6	72	22	2.510	80.4	72	22	1.935	76.6	11	83	58
								Fifth instar								
200	6-30	75	13	1.445	68.6	87	13	3.160	81.6	87	15	1.870	75.4	8	85	58
300	6-30	83	6	.970	68.6	100	14	2.750	81.6	83	12	1.830	75.4	6	85	58

Table 5.—Continued.- Daily Food Record *Melanoplus bivittatus* Based on Hourly Feeding Records—12-hour Day, Fort Collins, Colorado.
Food plant– Alfalfa

		Morning period				Noon period				Afternoon period						
Exp.	Date	Percentage feeding	Number periods feeding occurred	Amount food consumed	Mean hourly temp.	Percentage feeding	Number periods feeding occurred	Amount food consumed	Mean hourly temp.	Percentage feeding	Number periods feeding occurred	Amount food consumed	Mean hourly temp.	Number of individuals	Range of temp. Fahr. from 7 a.m. to 7 p.m. Max.	Min.
								First instar								
	1926															
11-A	5-18	88	11	.051	71.3	66	6	.048	79.7	77	8	.070	76.2	9	87	67
								Second instar								
	1927															
100	5-25	100	11	.207	74.6	100	15	.199	85	88	12	.153	79.6	9	87	61
	1926															
26-A	7-23	75	9	.290	64.3	62	13	.410	76.4	27	6	.160	71	8	80	58
								Third instar								
	1927															
100	6-1	100	21	.356	72.6	100	15	.245	85.2	100	12	.313	74.4	9	87	60
	1926															
14-A	6-2	50	7	.259	67.4	75	8	.161	77.7	75	7	.223	77.1	8	80	58
17-A	6-2	80	14	.443	71	60	8	.374	86	80	12	.604	78	10	90	58
21-A	7-20	80	11	.530	67	50	7	.300	77.2	100	13	.600	73.6	10	84.5	57.5
								Fourth instar								
	1927															
100	6-17	66	9	.315	69.6	77	9	.510	80.4	77	11	.670	76.6	9	83	58
								Fifth instar								
	1927															
100	6-30	100	8	.520	68.6	60	5	.234	81.6	60	5	.770	75.4	5	85	58
	1926															
22-A	7-20	61	15	6.160	67	77	23	6.050	77.2	77	23	5.970	73.6	18	84	57
25-A	7-23	61	13	5.020	69.6	72	24	4.980	77.5	77	23	5.030	70.8	18	80	62
								Adult males								
	1926															
24-A	7-23	43	11	3.500	67.3	75	16	4.440	76.6	81	22	6.030	69.6	16	80	60
23	7-20	58	14	5.860	67	76	17	7.810	77.2	82	24	7.270	73.6	17	84	57

The above considerations are based entirely upon laboratory observations, but it appears logical that the same results should be obtained under field conditions as long as the temperature is sufficiently high to be within the range of activity and since the grasshoppers react to temperature so as to maintain themselves in their optimum or as near it as possible. To make records of these data in the field, of course, would be difficult.

AMOUNT OF FOOD CONSUMED DAILY

A knowledge of the amount of food consumed daily for a given infestation of grasshoppers is of value to the field entomologist in making estimates of crop losses. Especially is this true when it is necessary to impress the value of control upon farmers.

Morril (45), working in Arizona, reported that grasshoppers eat approximately 1 gram of green alfalfa each 24 hours. This is somewhat more than the writer found for grasshoppers in Colorado. However, the higher temperatures, with warmer mornings and evenings of Arizona should permit much more feeding.

The writer, in experiments conducted as described by Morril, found that with a mean hourly temperature of 80 degrees F., adult females of *M. bivittatus* averaged .527 grams each over a period of 12 hours. After the amount which was cut and fell to the ground as waste was substracted, each grasshopper averaged .439 grams for a 12-hour day. The conditions of growth of alfalfa such as amount of shade, sunshine and irrigation will cause a variation, but alfalfa grown under normal irrigation averages about 8 square inches to 1 gram. According to this, each grasshopper ate an average of 3.512 square inches of alfalfa per day. This amount was within the limits of variation of gravid females as determined by measurements of areas eaten.

The writer found in his investigations that grasshoppers require greater quantities of one kind of food plant than another, and since the values of crops vary, it is also important to know the quantities that can be destroyed of each type of crop in order that accurate estimates of losses may be made. This phase has been kept in mind, and accordingly the writer has used plants in his experiments and expressed the results in terms of square inches. If it is desired these figures can later be expressed in weight.

It is difficult to state accurately the amount of food a grasshopper, or a given number of grasshoppers, will eat in a given day. The temperature, the kind of food, the age of the grasshop-

per, the sex, the stage of development, length of day and various other factors cause variation. The following statement will illustrate the extreme amount of variations. *M. bivittatus* feeding on lettuce may have a variation of from .02 square inches for newly hatched nymphs to 7.52 square inches for an adult female. Under constant temperature of 95 degrees and light, thus lengthening the feeding day to 24 hours, a female may eat as much as 11.30 square inches.

The following figures give the range for *M. bivittatus* feeding on alfalfa and lettuce during a 12-hour day and in temperatures ranging from 68 to 95 degrees F.

Instar	Alfalfa Square inches	Number of individuals	Lettuce Square inches	Number of individuals
1	.005- .035	301	.02- .14	56
2	.02 - .08	104	.04- .24	53
3	.03 - .16	76	.10- .692	66
4	.035- .360	43	.18-1.57	55
5	.10 - .25	35	.48-3.90	22
6	.30 -1.76	18	.68-8.80	36
7	-		.68-7.90	11
Adult females	.50 -4.32	52	2.00-7.52	21
Audlt males	.40 -2.64	47	1.50-5.90	14

There is a wide daily variation in the amount of food eaten by individuals of the same brood hatched from the same batch of eggs and kept apparently under the same conditions. In the case of adult *M. bivittatus* feeding on lettuce, the variation may be almost 4 square inches. Specific examples of this may be seen by examining Table 4. Not only do individuals of the same brood vary in the amount they eat per day but the same individuals under constant temperatures and apparently indentical conditions vary from day to day.

As stated before, accurate averages are hard to make due to many variable factors and especially to the fact that in a climate like Colorado the temperature varies greatly within a day and from day to day. The following figures give the average amount of leaf surface consumed in square inches for *M. bivittatus* during a 12-hour day under temperature conditions ranging within feeding activities, 65 to 95 degrees F.

Instar	Alfalfa square inches	Number grasshoppers studied	Lettuce square inches	Number grasshoppers studied
1	.012	301	.058	56
2	.030	104	.116	53
3	.078	76	.284	66
4	.107	43	.549	55
5	.557	35	1.622	22
6	1.100	18	2.678	36
7			2.435	11
Adult males	.950	52	2.666	21
Adult females	1.875	47	5.950	14

The above averages must be considered as being conservative. In the open a grasshopper probably gets considerably more exercise than one caged and it would appear logical that under such conditions it would need more food to maintain itself. Depending on the season, but normally, under field conditions it is possible for a grasshopper to maintain a higher mean hourly temperature than these records, and on many occasions to feed over longer periods.

A study of the average amount of food consumed by developing grasshoppers is very interesting. It clearly shows one of the advantages of poisoning while the grasshoppers are young. With each moult a grasshopper almost doubles the amount of food eaten daily. Adult females eat almost 100 times more food

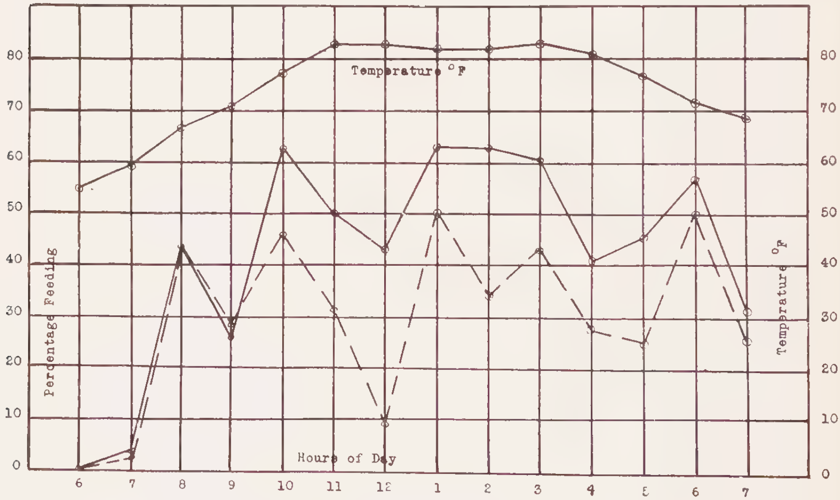

Fig. 6.—A comparison of the difference in the rate of feeding of nymphs of *Melanoplus bivittatus* on different plants. Upper line indicates the mean hourly temperature. Solid line represents feeding on lettuce based on 60 individuals. Broken line represents feeding on alfalfa based on 32 individuals.

per day than first instar nymphs. Aside from the losses incurred during the process of development, it is very evident that it required from 70 to 80 times more food per day to maintain an equal number of adult grasshoppers than first instar nymphs. Even within the same instar the amount eaten increases enormously as the grasshoppers grow older. The following example will illustrate:

Fourteen 1-day-old *Chortophaga viridifaciatus* ate an average of .082 square inches of lettuce each in 24 hours under a constant temperature of 95 degrees F. The maximum amount eaten by a single individual was .120 square inches, and the minimum amount was .060 square inches. At the age of 4 days these same grasshoppers under apparently the same conditions ate an average of .145 square inches each, with a maximum of .200 square inches and a minimum of .092 square inches.

Table 6.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Alfalfa

Exp.	Date	Amount of food Consumed			Number	Temp. Fahr.			Hours of feeding		Spe-
	1927	Max.	Min.	Ave.	grass-hoppers	Max.	Min.	Hourly mean	a.m.	p.m.	cies
					First instar						
	5-4	.011	.001	.004	15				8	8	M.b.*
	5-5	.025	.001	.010	31				8	8	"
	5-6	.022	.001	.006	21				8	8	"
	5-6			.014	45				8	8	"
	5-7	.019	.001	.006	17				8	8	"
7a	5-18	.017	.003	.011	10	78	62	68.7	8	7	"
7b	7-3	.032	.010	.021	15	83	66	74.9	8	7	"
10	5-18	.014	.003	.008	7	64.5	48.5	57.5	6	6	"
11	5-18	.035	.001	.018	9	90	64	74.5	6	6	"
12	5-21	.017	.014	.015	2	90	64	77.5	5	7	"
13	5-21	.012	.002	.005	3	75.5	57	67.7	5	7	"
6	5-27	.020	.013	.015	3	80	61	70.5	7	7	"
6	5-27	.010	.001	.004	5	71	56	62.7	7	7	"
5	5-28	.005	.005	.005	1	65.5	53.5	59.3	7	7	"
3	5-29	.011	.008	.010	3	90	66	79.7	7	7	"
3	5-29	.008	.003	.005	4	68	55	63.4	7	7	"
15	6-2	.032	.007	.015	5	80	55	70.8	5	7	"
19	6-2	.032	.003	.014	8	80	58	76	5	7	"
2	6-5	.012	.004	.009	3	78	70	74.3	7	7	"
2	6-5	.009	.004	.007	4	73	60	66	7	7	"
100—10	5-11	.014	.002	.008	9	86	55	76.5	7	7	"
100—10	5-17	.035	.020	.027	9	89	60	79.2	7	7	"
100—10	5-18	.020	.005	.013	7	86	55	75	7	7	"
16—21	4-23	.025	.010	.016	7	84	61	76	7	7	M.f-r

*M. b.—*Melanoplus bivittatus*

M. f-r—*Melanoplus femur-rubrum*

Table 6.—Continued.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Alfalfa

Exp.	Date 1927	Amount of food Consumed Max.	Min.	Ave.	Number grass-hoppers	Temp. Fahr. Max.	Min.	Hourly mean	Hours of feeding a.m. p.m.	Species
				Second instar						
	5-4	.035	.002	.013	15				8 - 8	M.b
	5-5	.040	.001	.019	12				8 - 8	”
	5-6	.030	.001	.013	12				8 - 8	”
	5-7	.020	.001	.009	7				8 - 8	”
12	5-21	.032	.032	.032	1	90	64	77.5	7 - 7	”
6	5-27	.042	.002	.029	5	80	61	70.5	7 - 7	”
6	5-27	.011	.003	.006	4	71	56	62.7	7 - 7	”
5	5-28	.009	.002	.005	2	65.5	53.5	59.3	7 - 7	”
5	5-28	.028	.011	.017	3	84	64	73.8	7 - 7	”
3	5-29	.019	.018	.018	2	90	66	79.7	7 - 7	”
	6-2	.015	.015	.015	1				7 - 7	”
15	6-2	.048	.006	.027	2	80	55	70.8	5 - 7	”
19	6-2	.120	.017	.066	3	90	58	76	5 - 7	”
2	6-5	.040	.006	.018	3	73	60	66	7 - 7	”
2	6-5	.035	.018	.026	2	78	70	74.3	7 - 7	”
100—10	5-25	.080	.045	.062	9	87	61	78.9	7 - 7	”
A-E	5-17	.085	.050	.062	5	89	60	79.9	7 - 7	”
A-E	5-18	.045	.027	.038	5	86	55	75.7	7 - 7	”
A-E	5-19	.070	.045	.056	4	84	56	75.6	7 - 7	”
A-E	5-20	.055	.030	.045	4	86	58	77.8	7 - 7	”
A-E	5-23	.070	.030	.055	3	82	51	70.2	7 - 7	”
16—21	5-5	.050	.005	.027	5	85	62	76.1	7 - 7	M.f-r
16—21	5-6	.060	.005	.027	6	85	60	77.2	7 - 7	”
16—21	5-10	.050	.025	.040	4	91	69	79.5	7 - 7	”
16—21	5-11	.065	.025	.045	3	92	51	77		”
				Third instar						
12	5-21	.043	.011	.027	2	90	64	77.5	5 - 7	M.b.
6	5-27	.027	.015	.021	3	71	56	62.7	7 - 7	”
6	5-27	.065	.030	.053	3	80	61	70.6	7 - 7	”
5	5-28	.062	.028	.041	3	84	64	73.8	7 - 7	”
3	5-29	.031	.030	.030	2	68	55	63.4	7 - 7	”
3	5-29	.075	.032	.057	3	90	66	79.7	7 - 7	”
14	6-2	.147	.005	.077	6	80	55	70.8	5 - 7	”
17	6-2	.170	.025	.077	5	90	58	76	5 - 7	”
2	6-5	.082	.010	.040	4	78	70	74.3	7 - 7	”
2	6-5	.075	.025	.050	2	73	60	66	7 - 7	”
21	7-20	.250	.020	.149	10	84	57	72	5 - 8	”
26	7-23	.170	.050	.107	8	80	58	69.6	5 - 8	”
100—14	6-1	.138	.054	.101	9	87	57	79	6 - 7	”
A-E	5-26	.160	.100	.131	4	89	68	80	7 - 7	”
A-E	5-31	.120	.090	.105	4				7 - 7	”
A-E	6-1	.080	.057	.068	4	90	57	75	7 - 7	”
A-E	6-2	.075	.030	.046	3	89	58	74	7 - 7	”
1—4	4-25	.240	.240	.240	1	86	56	79	7 - 7	”
16—21	5-10	.080		.080	1	91	69	79.5	7 - 7	M.f.r.
16—21	5-11	.050	.030	.040	2	92	51	77	7 - 7	”
16—21	5-11	.095	.030	.068	4	89	60	79.9	7 - 7	”
16—21	5-17	.095	.030	.068	4	89	60	79.9	7 - 7	”
16—21	5-18	.065	.038	.049	4	86	55	75.7	7 - 7	”
16—21	5-19	.070	.040	.058	3	84	56	75.6	7 - 7	”
16—21	5-20	.060	.060	.060	2	86	58	77.8	7 - 7	”

Table 6.—Continued.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Alfalfa

Exp.	Date 1927	Amount of food Consumed Max.	Min.	Ave.	Number grass-hoppers	Temp. Fahr. Max.	Min.	Hourly mean	Hours of feeding a.m. p.m.	Spe-cies
16—21	5-23	.085	.060	.068	3	82	51	70.2	7 - 7	"
16—21	5-26	.060		.060	1	89	68	80	7 - 7	"
16—21	6-1	.110		.110	1	90	57	75	7 - 7	"
16—21	6-2	.090		.090	1	89	58	74	7 - 7	"
				Fourth instar						
6	5-27	.115	.080	.097	2	80	61	70.5	7 - 7	M.b.
6	5-27	.073	.051	.061	2	71	56	62.7	7 - 7	"
5	5-28	.081	.034	.050	3	84	64	73.8	7 - 7	"
5	5-28	.035	.032	.033	2	65.5	53.5	59.3	7 - 7	"
3	5-29	.170	.040	.099	3	90	66	79.7	7 - 7	"
3	5-29	.055	.035	.042	2	68	55	63.4	7 - 7	"
14	6-2	.112	.060	.086	2	80	55	70.8	5 - 7	"
17	6-2	.612	.004	.209	5	90	58	76	5 - 7	"
2	6-5	.110	.030	.078	4	78	70	74.3	7 - 7	"
2	6-5	.130	.047	.084	3	73	60	66	7 - 7	"
100—14	6-17	.290	.040	.161	9	83	57	72	6 - 8	"
A-E	6-7	.230	.110	.171	4	91	70	82	7 - 7	"
1— 4	5-25	.025	.200	.220	2	86	56	79	7 - 7	"
16—21	5-19	.080		.080	1	84	56	75.6	7 - 7	M.f.r.
16—21	5-19	.120	.100	.110	2	86	56	77.8	7 - 7	"
16—21	5-23	.100		.100	1	82	51	70.2	7 - 7	"
16—21	5-26	.090	.070	.080	2	89	68	80	7 - 7	"
16—21	6-1	.100	.075	.090	3	90	57	75	7 - 7	"
16—21	6-2	.075	.035	.053	3	89	58	74	7 - 7	"
				Fifth instar						
—25	7-23	1.68	.430	.83	18	80	58	69.6	5 - 8	M.b.
100—14	6-24	1.230	.220	.700	9	93	65	83	7 - 7	"
100—14	6-30	.470	.100	.233	4	85	58	73	7 - 7	"
A-E	6-24	.620	.210	.425	4	92	65	84	7 - 7	"
16—21	6-1	.245		.245	1	90	57	75	7 - 7	M.f.r.
16—21	6-2	.200		.200	1	89	58	74	7 - 7	"
				Sixth instar						
22	7-20	1.76	.300	1.10	18	84	57	72	5 - 8	M.b.
				Adult females						
24		2.64	2.50	2.57	2	80	58	69.6	6 - 8	M.b.
28	10-22	4.32	.08	2.12	20	78	64	69.4	8 - 5	"
37	10-29	1.13	.04	.354	25	66	48	61.7	8 - 5	"
	11-4	4.16	.15	1.63	27				8 - 5	"
				Adult males						
23	7-20	2.30	.46	1.23	17	84	57	72	6 - 8	M.b.
24	7-23	2.64	.15	.87	16	80	58	69.6	6 - 8	"
27	10-22	1.51	.01	.75	19	78	64	69.4	8 - 5	"
38	10-29	.47	.01	.174	14	66	48	61.7	8 - 5	"

Table 6.—Continued.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Lettuce

Exp.	Date 1927	Amount of food Consumed Max.	Min.	Ave.	Number grass-hoppers	Temp. Fahr. Max.	Min.	Hourly mean	Hours of feeding a.m. p.m.	Species
				First instar						
1—4	3-30	.037		.037	1	81	65	73	7 - 7	M.b.
1—4	3-31	.039		.039	1	81	68	74	7 - 7	"
1—4	4-4	.047		.047	1	81	49	70	7 - 7	"
1—4	4-7	.025		.025	1	84	71	76	7 - 7	"
200—14	5-11	.080	.020	.043	14	86	55	76.4	7 - 7	"
200—14	5-13	.115	.040	.070	14	92	66	79.4	7 - 7	"
300—14	5-17	.140	.060	.088	14	89	55	79.2	6 - 7	"
A—200	5-6	.082		.082	5	91	69	79.5	7 - 7	"
A—200	5-10	.097		.097	5	91	69	79.5	7 - 7	M.b.
5—14	4-23	.050	.015	.038	6	84	61	76	7 - 7	M.f.r.
				Second instar						
1—4	3-29	.080	.065	.072	2	74	45	70	7 - 7	M.b.
1—4	3-30	.142	.105	.123	2	81	65	73	7 - 7	"
1—4	3-31	.100	.088	.094	2	81	68	74	7 - 7	"
1—4	4-9	.145		.145	1	81	65	74	7 - 7	"
1—4	4-12	.180		.180	1	80	65	73	7 - 7	"
1—4	4-13	.165		.165	1	83	65	73	7 - 7	"
1—4	4-14	.135		.135	1	77	67	71	7 - 7	"
1—4	4-4	.020		.020	1	81	49	70	7 - 7	"
1—4	4-11	.050		.050	1	78	54	70	7 - 7	"
F-M	5-18	.230	.115	.171	7	86	55	75.7	7 - 7	"
F-M	5-20	.180	.140	.151	6	86	58	77.8	7 - 7	"
F-M	5-23	.125	.095	.108	4	82	51	70.2	7 - 7	"
300—14	5-23	.187	.055	.130	12	85	50	71.4	7 - 7	"
300—14	5-25	.145	.060	.105	12	87	61	78.9	7 - 7	"
200—14	5-25	.125	.042	.082	13	89	51	75.3	7 - 7	"
5—14	5-6	.220	.100	.156	5	85	60	77.2	7 - 7	M.f.r.
5—14	5-5	.200	.090	.150	4	85	62	76.1	7 - 7	"
5—14	5-10	.205	.145	.170	3	91	69	79.5	7 - 7	"
5—14	5-11	.240	.200	.220	2	92	51	77	7 - 7	"
				Third instar						
1—4	3-30	.100		.100	1	81	65	73	7 - 7	M.b.
1—4	3-31	.165		.165	1	81	68	74	7 - 7	"
1—4	4-4	.265	.080	.172	2	81	49	70	7 - 7	"
1—4	4-7	.420	.285	.353	3	84	71	76	7 - 7	"
1—4	4-9	.260	.172	.216	2	81	65	74	7 - 7	"
1—4	4-11	.167	.152	.159	2	78	54	70	7 - 7	"
1—4	4-12	.155		.155	1	80	65	73	7 - 7	"
1—4	4-13	.097		.097	1	83	65	73	7 - 7	"
1—4	4-14	.185		.185	1	77	67	73	7 - 7	"
1—4	4-18	.350		.350	1	85	73	81	7 - 7	"
1—4	4-19	.250		.250	1	76	72	73	7 - 7	"
1—4	4-20	.540		.540	1	83	70	77	7 - 7	"
1—4	4-21	.610		.610	1	88	69	78	7 - 7	"
1—4	4-22	.530	.235	.382	2	88	70	79	7 - 7	"
1—4	4-23	.440	.290	.365	2	84	61	76	7 - 7	"
1—4A	4-26	.430		.430	1	93	68	84	7 - 7	"
1—4A	4-27	.090		.090	1	87	62	78	7 - 7	"
F-M	5-26	.480	.180	.331	7	89	68	80	7 - 7	"

Table 6.—Continued.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Lettuce

Exp.	Date 1927	Amount of food Consumed Max.	Min.	Ave.	Number grass-hoppers	Temp. Fahr. Max.	Min.	Hourly mean	Hours of feeding a.m. p.m.	Spe-cies
F-M	6-1	.440	.200	.299	6	90	57	75	7 - 7	”
F-M	6-2	.260	.155	.212	5	89	58	74	7 - 7	”
300—14	6-2	.427	.175	.293	11	89	57	72	7 - 7	”
200—14	6-1	.692	.044	.337	13	87	57	79	6 - 7	”
5—14	5-10	.310	.290	.301	3	91	69	79.5	7 - 7	M.f.r.
5—14	5-11	.320	.280	.300	2	92	51	77	7 - 7	”
5—14	5-18	.450	.220	.350	3	86	55	75.5	7 - 7	”
5—14	5-20	.315	.270	.292	2	86	58	77.8	7 - 7	”
				Fourth instar						
1—4	4-11	.100		.100	1	78	54	70	7 - 7	M.b.
1—4	4-12	.300		.300	1	80	65	73	7 - 7	”
1—4	4-13	.280		.280	1	83	65	73	7 - 7	”
1—4	4-14	.440		.440	1	77	67	73	7 - 7	”
1—4	4-18	.720	.540	.653	3	85	73	81	7 - 7	”
1—4	4-19	.530	.520	.525	3	76	72	73	7 - 7	”
1—4	4-20	.800	.570	.685	2	83	70	77	7 - 7	”
1—4	4-21	.850	.660	.755	2	88	69	78	7 - 7	”
1—4	4-22	.820	.820	.820	2	88	70	79	7 - 7	”
1—4	4-23	.330	.280	.305	2	84	61	76	7 - 7	”
1—4	4-24	.430		.430	1	93	68	84	7 - 7	”
1—4	4-28	.500		.500	1	90	65	78	7 - 7	”
1—4A	5-5	.750	.500	.625	2	85	62	76.1	7 - 7	”
1—4A	5-6	.810	.680	.745	2	85	60	77.2	7 - 7	”
11	6-1	.460		.460	1	90	57	75	7 - 7	”
11	6-2	.310		.310	1	89	58	74	7 - 7	”
F-M	6-7	.770	.460	.560	6	91	70	82	7 - 7	”
300—14	6-17	.930	.010	.550	11	83	56	72	6 - 8	”
200—14	6-17	1.510	.100	.610	10	83	56	72	6 - 8	”
1—3	6-24	1.570	1.090	1.330	2	92	65	84	7 - 7	”
5—14	5-18	.490		.490	1	86	55	75.7	7 - 7	M.f.r.
5—14	5-20	.720	.300	.473	3	86	58	77.8	7 - 7	”
5—14	5-23	.620	.210	.405	4	82	51	70.2	7 - 7	”
5—14	5-26	1.000	.380	.666	6	89	68	80	7 - 7	”
				Fifth instar						
1—4	4-21	.910		.910	1	86	69	78	7 - 7	M.b.
1—4	4-22	1.100		1.100	1	88	70	79	7 - 7	”
1—4	4-23	.900		.900	1	84	61	76	7 - 7	”
1—4	4-26	1.520	.900	1.210	2	93	68	84	7 - 7	”
1—4	4-27	1.260	.700	1.025	2	87	62	78	7 - 7	”
1—4	4-28	1.390	1.050	1.220	2	90	65	78	7 - 7	”
1—4A	5-5	.520	.480	.500	2	85	62	76.1	7 - 7	”
1—4A	5-6	1.080	.640	.860	2	85	60	77.2	7 - 7	”
1—4A	5-11	1.780		1.780	1	92	51	77	7 - 7	”
1—4A	5-12	2.480		2.480	1	86	69	78.1	7 - 7	”
1—4A	5-13	2.660		2.660	1	92	66	79.1	7 - 7	”
1—4A	5-16	2.460		2.460	1	87	59	78.3	7 - 7	”
1—4A	5-17	3.150		3.150	1	89	60	79.2	7 - 7	”
1—4A	5-18	2.420		2.420	1	86	55	75	7 - 7	”
1—4A	5-19	1.800		1.800	1	83	58	74.6	7 - 7	”
1—4A	5-20	1.500		1.500	1	86	58	77.8	7 - 7	”
1—4A	5-23				1	85	50	71.4	7 - 7	”

Table 6.—Continued.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Lettuce

Exp.	Date 1927	Amount of food Consumed Max.	Min.	Ave.	Number grass-hoppers	Temp. Fahr. Max.	Min.	Hourly mean	Hours of feeding a.m. p.m.	Species
				Sixth instar						
1—4A	5-6	1.100		1.100	1	85	60	77.2	7 - 7	M.b.
1—4A	5-9	2.400		2.400	1	96	62	78.8	7 - 7	”
1—4A	5-10	2.330		2.330	1	91	69	79.5	7 - 7	”
1—4A	5-11	2.460	1.500	2.130	2	92	51	77	7 - 7	”
1—4A	5-12	2.670	1.520	2.010	3	86	69	78.1	7 - 7	”
1—4A	5-13	3.720	2.130	2.763	3	92	65	79.1	7 - 7	”
1—4A	5-16	1.840	1.140	1.593	3	87	59	78.3	7 - 7	”
1—4A	5-17	3.350	2.520	3.006	3	89	60	79.2	7 - 7	”
1—4A	5-18	2.560	.680	1.680	3	86	55	75	7 - 7	”
1—4A	5-19	2.750	1.850	2.300	2	83	56	74.6	7 - 7	”
1—4A	5-20	2.200	1.600	1.900	2	86	58	77.8	7 - 7	”
1—4A	5-23	.680	.100	.390	2				7 - 7	”
1—4A	5-26	3.800		3.800	1	88	68	80.3	7 - 7	”
4	5-31	2.700		2.700	1	79	54	70	7 - 8	”
4	6-1	3.800		3.800	1	87	60	76	7 - 8	”
4	6-2	3.260		3.260	1	89	58	74	7 - 8	”
4	6-7	3.900		3.900	1	88	72		7 - 8	”
				Seventh instar						
1—4A	5-23	.960		.960	1					M.b.
1—4A	5-26	1.900	1.770	1.835	2	88	68	80.3	7 - 8	”
1—4	5-31	2.700	1.460	2.080	2	79	54	70	7 - 8	”
1—4	6-1	2.440	2.400	2.420	2	87	60	76	7 - 8	”
1—4	6-2	2.360	.340	1.350	2	89	58	74	7 - 8	”
1—4	6-7	3.900		3.900	1	88	70	81	7 - 8	”
4A	6-24	4.500		4.500	1	93	65	83	7 - 8	”
				Last instar (*Chortophago virid*)						
	4-8	1.470		1.470	1	83	65	74	7 - 8	
	4-11	.860		.860	1	78	54	70	7 - 8	
	4-12	1.600		1.600	1	80	65	73	7 - 8	
	4-13	1.280		1.280	1				7 - 8	
	4-14	1.590		1.590	1				7 - 8	
				Adult females (*Chortophago virid*)						
	4-22	2.450		2.450	1	88	70	79	7 - 8	
	4-23	2.850		2.850	1	84	61	76	7 - 8	
	4-26	2.120		2.120	1	93	68	84	7 - 8	
	4-27	2.940		2.940	1	87	62	78	7 - 8	
	4-28	2.370	.560	1.417	4	90	65	78	7 - 8	
	5-5	1.940	1.520	1.705	4	85	62	76.1	7 - 8	
				Adult males (*Chortophago virid*)						
	4-28	.960	.320	.688	10	90	65	78	7 - 8	
	5-5	.830	.380	.643	9	85	62	76.1	7 - 8	

Table 6.—Continued.—Notes on the Amount of Food Consumed During a Day by Grasshoppers.

Food plant—Lettuce

Exp.	Date 1927	Amount of food Consumed Max.	Min.	Ave.	Number grass-hoppers	Temp. Fahr. Max.	Min.	Hourly mean	Hours of feeding a.m. p.m.
				Adult females—*M. bivittatus*					
1—4	6-17	6.680	6.120	6.400	2				7 - 8
1—4	6-23	4.820	4.760	4.790	2				7 - 8
1—4	6-24	7.520	7.000	7.260	2	93	65	83	7 - 8
1—4A	6-30	7.010	4.800	5.843	3	85	58	73	7 - 8
1—4A	7-2	6.000	3.900	5.266	3	89	58	74	7 - 8
300—14	7-15	6.390	5.900	6.145	2	85	55	73	7 - 8
				Adult males—*M. bivittatus*					
1—4	5-31	.820		.820	1	79	54	70	7 - 8
1—4	6-1	2.750		2.750	1	87	60	76	7 - 8
1—4	6-2	2.740		2.740	1	89	58	74	7 - 8
1—4	6-7	3.700		3.700	1	88	70	81	7 - 8
1—4	6-17	2.420	1.130	1.775	2	83	56	72	7 - 8
1—4	6-23	5.110	2.000	3.555	2				7 - 8
1—4	6-24	4.610	1.840	3.225	2	93	65	83	7 - 8
1—4	6-30	2.350	1.210	1.780	2	85	58	73	7 - 8
1—4	7-2	3.800	2.000	2.900	2	89	58	74	7 - 8
300—14	7-15	5.900	1.950	3.421	7	85	55	73	7 - 8
				Adult females—*M. femur-rubrum*					
9—14	6-24	2.760	1.800	2.280	2	92	65	84	7 - 8
9—14	6-24	1.050		1.050	1	92	65	84	7 - 8
	7-1	3.780	2.060	2.920	2	92-95	constant temp.		
	7-5	4.000	3.500	3.750	2	"	"	"	
				Adult males—*M. femur-rubrum*					
	7-1	1.860	1.580	1.720	2	92-95	constant temp.		
	7-5	2.170	1.820	1.995	2	"	"	"	

AMOUNT OF FOOD EATEN BY GRASSHOPPERS WHEN FEEDING ON DIFFERENT FOOD PLANTS

Elsewhere in this paper it is shown that different food plants, such as alfalfa and lettuce apparently have no effect on the rate of development of grasshoppers, but there is an enormous difference in the amount eaten when expressed either by green weight or in square inches of leaf surface. As already shown the amount eaten by different individuals and the amount eaten by the same individuals vary from day to day even when the grasshoppers are kept under apparently indentical conditions, therefore we should have the ratio between different food plants varying slightly from day to day. This always occurs. Speaking in broad terms, *M. bivittatus, M. differentialis* and *M. femur-rubrum* feeding under the same conditions all eat from 3 to 4 times as much lettuce as alfalfa per day, when the quantity is expressed either in green weight or in square inches of leaf

surface. Comparative studies of Tables 5 and 6 show indications of this variation.

In an experiment in which comparative studies were made for the first 4 instars with individuals of *M. bivittatus* and *M. femur-rubrum* the following results were obtained: A total of 35 individuals of *M. femur-rubrum* feeding on alfalfa and 34 on lettuce, over a period of ten 12-hour feeding days in which the mean hourly temperature ranged from 70.2 to 79.5 degrees F., the ratio of the amount of alfalfa to lettuce eaten varied from 1:2.3 to 1:7.5 with an average of 1:4.9 for all instars. With *M. bivittatus* in which a total of 63 individuals were fed on alfalfa and 96 on lettuce, over a period representing eleven 12-hour feeding days in which the mean hourly temperature varied from 70.2 to 82 degrees F., the ratio of alfalfa to lettuce varied from 1:1.9 to 1:5.3, with an average of 1:3.4.

It is difficult to account for the entire amount of variation. To do so it would be necessary to know to what extent a grasshopper was capable of digesting the nutrients in each material utilized. The following figures give the general analysis for alfalfa and lettuce:

	Alfalfa*		Lettuce**	
Water	74.7	percent	94.0	percent
Ash	2.4	"	0.9	"
Crude protein	4.5	"	1.2	"
Fat	1.0	"	0.3	"
Carbohydrate	10.4	"	2.9	"
Fiber	7.0	"	0.7	"

*Analysis by Henry and Morrison (83)

**Analysis by Sherman (84)

According to the above analyses, alfalfa contains 4.26 times as much dry matter as lettuce, 3.7 times as much protein, 3.5 times as much carbohydrate, 3.3 times as much fat, 2.6 times as much ash and 10 times as much fiber. Alfalfa and lettuce leaves of equal thickness weigh approximately the same per square inch of leaf surface. Thus, it would appear that the percentage of nutrient material in each food would account for most of the difference in the amount eaten.

WASTE OCCURRING WHEN FEEDING

Everyone observing the feeding habits of grasshoppers has noticed the enormous waste that occurs by the biting off of parts of the plant which fall to the ground and are never eaten. To make a study of this in a comparative way is difficult, due to the many variable factors that must be considered. Males and females never eat the same amount of food; the amount of food

eaten at different temperatures is never the same, and due to the difference in size of the grasshoppers and the quantity of food consumed, small nymphs do not waste as much as large nymphs and adults. All these factors cause a variation in waste and since they must be considered, the problem is extremely complex.

An elementary study was made by the writer on the amount of waste occurring on alfalfa by adult females of *M. bivittatus*. Fifty adult females over a period of 12 hours, from 7 a. m. to 7 p. m., at a mean hourly temperature of 80 degrees F., destroyed 26.352 grams of green alfalfa of which 4.404 grams were cut and never eaten. This is 16.7 percent of the amount destroyed.

THE EFFECT OF THE LENGTH OF DAY ON FEEDING

The length of day, providing the temperature remains within the limits of activity, should affect the feeding operations of grasshoppers. These facts are generally known, but there are few records in literature which give specific information on this question. In the case of grasshoppers, the question is of economic value since control is based to a great extent on the feeding habits.

Experimental evidence shows that high mean hourly temperature is conducive to an increased metabolic activitiy and rate of food consumption. Temperature is often one of the factors which limits feeding during a day. During summer there can be found in Colorado, days which have temperatures that would permit long hours of feeding.

Results obtained in a study of daily food habits indicated that the length of day has a special significance in the amount of food consumed by grasshoppers, so an experiment was performed to obtain definite data covering this point.

Three species of grasshoppers *M. bivittatus, M. differentialis* and *Chortophaga viridifaciatus* were studied. Several stages in their development, including males and females were considered. The insects were fed under constant temperature and light conditions for a period of 24 hours. A constant temperature of 95 degrees F. was employed. The amount of food eaten was recorded at 12- and 24-hour intervals. The summarized results indicated that the length of feeding day has an important bearing on the quantity of food a grasshopper will eat. Feeding occurred over the entire 24-hour period, and the amount of food eaten was greatly increased. There was some range of variation for individuals, some individuals increasing the quantity eaten but slightly over the 12-hour period, while others more than doubled the quantity.

These variations are to be expected since on any day there is a decidedly wide range as to the feeding activities of individuals.

In summarizing a series of 6 experiments in which 40 individuals were studied it was found that there was an average of from 56.7 to 74.6 percent increase in the 24-hour day over the 12-hour.

The detailed results are given in Table 7.

Table 7.—Notes on the Amount of Food Consumed in Square Inches During Long and Short Days by Grasshoppers. Constant Temperature 95 Degrees F. Food plant—Lettuce

Exp.	Date 1927	Amount food consumed in 12 hours 8 a. m. - 8 p. m.			Amount food consumed in 24 hours—Light 24 hours 8 a. m. - 8 a. m.			Number Grasshoppers	Amount increase over 12 hours	Percentage increase over 12 hours
		Max.	Min.	Ave.	Max.	Min.	Ave.			
					Chortophaga viridifaciatus First instar					
1	7-15	.065	.045	.051	.120	.060	.082	14	.031	60.7
2	7-18	.115	.057	.083	.200	.092	.145	14	.062	74.6
					M. bivittatus Sixth instar					
3	7-15	7.800	4.540	6.170	10.520	9.480	10.000	2	3.830	62
4	7-18	5.300	1.950	3.665	11.300	2.950	6.027	4	2.362	64.4
					M. differentialis—Males					
5	8-3	5.350	2.580	3.965	8.450	3.980	6.215	2	2.250	56.7
					M. differentialis—Females					
6	8-3	4.660	2.650	3.750	8.660	2.650	6.074	4	2.325	62

MOULTING AND ITS EFFECT ON FEEDING

Shortly before a grasshopper moults there is a rapid decline in the amount of food eaten. Usually it does not eat the day prior to moulting. The number of hours between the time feeding ceases and the skin is shed will vary. High temperatures shorten the time considerably. Often there is a period of 24 hours or more in which no feeding takes place. Immediately after moulting grasshoppers do not eat for several hours, but will begin to eat soon after the chitin hardens.

It is rather difficult to correlate the moulting with poor results that are often obtained with poisoned-bran mash. It is known that nymphs hatched on the same day and from the same egg pod under field conditions will vary in their size and moulting dates before reaching maturity. In a field containing a large number of nymphs hatched at approximately the same time there will be a peak in the curve representing their dates of

moulting. At this peak it appears plausible to believe that poisoned-bran mash would be least effective. If only 25 percent of the grasshoppers moulted on this date, the efficiency of the bait would be materially affected. Regardless of time of hatching, this must be considered as one of the factors which reduce the efficiency of bait. In the laboratory studies this was a big factor in the average rate of food consumption for a series. Fasting on the day before and the day of moulting was always very noticeable. Often an individual would not eat for 2 days during the moulting period.

DIFFERENCE IN THE RATE OF FOOD CONSUMPTION BETWEEN ADULT MALES AND FEMALES

Adult females are larger than males and it would be natural for them to eat greater quantities of food. In addition to this they must eat to produce the large number of eggs which they lay. Males must also eat to produce the sperms as well as to maintain their bodies.

However, after considering the difference in body weight and size of males and females it appears that more food is required for egg production than sperm production. The difference in the amount of food eaten by the sexes is great. On comparing 113 males against 94 females, it was found that the females ate from 1.8 to 3.6 or an average of 2.5 times more food than males in a 12-hour day. Computing this on the basis of percentage, the females of this series ate from 80 to 260.5 percent more food per day than the males. Table 8 gives the details.

Table 8.—A Comparison of the Amount of Food Consumed Daily by Adult Male and Female Grasshoppers.

Exp.	Date	Species	Ave. amount food consumed sq. in. Males	Females	Number grasshoppers Males	Females	Percentage increase*	Food plant
1-1	6-20-27	M.b.**	.950	1.840	52	42	93.6	Alfalfa
1-4	6-17-27	"	1.775	6.400	2	2	260.5	Lettuce
1-4	7-2-27	"	2.900	5.266	2	3	81.5	"
1-4	6-30-27	"	1.780	5.843	2	3	228.1	"
27	10-22-26	"	.720	2.146	20	20	198	Alfalfa
2-2	5-5-27	C.v.	.643	1.705	9	4	165.1	Lettuce
2-4	7-1-27	M.f.r.	1.851	3.335	4	4	80.1	"
2-3	6-23-27	M.b.	2.666	5.950	20	14	123.1	"
1-4	6-24-27	"	3.225	7.260	2	2	125.1	"

*Percentage increase of females over males.

**M.b.—*Melanoplus bivittatus.*

C.v.—*Chortophaga viridifaciatus.*

M.f.r.—*Melanoplus femur-rubrum.*

DIFFERENCE IN THE AMOUNT OF FOOD EATEN BY DIFFERENT SPECIES

To obtain an index of the differences in the amount of food eaten by adults of different species, a comparison was made with *Melanoplus bivittatus, M. differentialis* and *M. femur-rubrum*.

As size would indicate, the difference in the amount eaten is quite noticeable between the large and small species. *Melanoplus bivittatus* and *M. differentialis,* the 2 larger species, eat approximately the same amount with slight variations, while *M. femur-rubrum* eats considerably less. It is not uncommon to find females of *M. bivittatus* eating from 4 to 7.5 square inches of lettuce during a 12-hour day. *M. femur-rubrum* under the same conditions, will eat from 2 to 4 square inches. The same condition occurs in the males, *M. bivittatus* commonly eating from 2.5 to 5 square inches and *M. femur-rubrum* eating from 1.5 to 2 square inches of lettuce under the same conditions. Comparative studies made with males of *M. differentialis* and *M. femur-rubrum* under constant temperature of 95 degrees F. for a 12-hour period showed that the former avereaged 3.750 square inches of lettuce and the latter averaged 1.857 square inches.

A study of the average amount of food consumed during a 12-hour day for all individuals under temperature conditions from 68 to 95 degrees F. showed that females and males of *M. bivittatus* average 5.95 and 2.66 square inches of lettuce respectively while *M. femur-rubrum* averaged 2.50 and 1.85 square inches.

The above is a significant factor when considering grasshopper damages. A field infested with *M. bivittatus.* or *M. differentialis* will suffer twice the loss each day that it would if infested with one of the smaller species such as *M. femur-rubrum* in the same numbers.

THE EFFECT OF AGE OF ADULT ON FOOD CONSUMED

As long as the adults are active and producing eggs or sperms, the rate of food consumption found in newly emerged adults appears to be maintained for a period of at least 30 days. Table 9 shows this for both males and females of *M. bivittatus.*

Table 9.—Showing Relative Rate of Food Consumption over a Period of 30 Days for Adults.

Food plant—Lettuce

Date	Female number	Female number	Male number	Male number	Temperature Min.	Max.	Mean
1927	1	4	2	3			Hourly
5-31			.820		54	79	70
6-1			2.750		60	87	76
6-7			3.700		70	88	81
6-12			2.740		58	89	74
6-17	6.680	6.120	1.870	2.420			
6-23	4.820	4.760	2.000	5.110			
6-24	7.000	7.52	1.841	4.610	65	93	83
6-30	5.720	7.010	1.210	2.350			
7-2	6.000	5.900	2.000	3.800			

Grasshoppers collected from the field that gave indications of being very old ate equally as much as young adults under the same conditions. This was shown by the following experiment: In the fall of 1926, a series of old males and gravid females of *M. bivittatus.* was collected for study. The battered condition of the wings gave evidence of their age. On October 22, 20 females and 19 males were fed alfalfa individually and results recorded. The females ate an average of 2.126 square inches each while the males ate an average of 0.757 square inches each. The temperature ranged from 64 to 77 degrees F. with a mean hourly temperature of 69.6 degrees F. This amount is equal to as much as newly emerged males and females would eat under the same conditions.

NUMBER OF FEEDING PERIODS DURING A DAY

If a day is divided into 12 feeding periods of 1 hour each, a knowledge of the number of these periods in which a grasshopper will take food is of value in estimating the chances it has of being poisoned with bait. Experimental evidence indicates that the number of periods is very variable. Such factors as temperature and kind of food available seem important.

With regard to temperature, as stated before, very little feeding occurs below 65 to 68 degrees F. Above these temperatures the amount of food consumed, as well as the number of feeding periods, increase.

The kind of food plant also causes a wide variation in the number of feeding periods during the day. Animals given identical conditions except for difference in food show a distinct variation. Table 10 shows the effect of lettuce and alfalfa on the frequency of feeding as indicated by a study of 559 individual grasshoppers of *M. bivittatus.*

Table 10.—Notes on Number of Feeding Periods During a Day for *Melanoplus bivittatus.*

Date	Exp.	Number grass-hoppers	Number hourly feeding periods Total	Min.	Max.	Ave.	Temperature Fahr. Max.	Min.	Mean	Food	Length of day a.m.-p.m.
					First instar						
5-16-27	200	13	50	1	6	3.8	85.5	59	70.6	Lettuce	7 - 7
5-17-27	300	13	97	5	8	6.9	89	60	78.2	"	7 - 7
5-18-26	10	8	15	1	4	1.9	64.5	48.5	57.5	Alfalfa	6 - 6
5-18-26	11	9	25	1	4	2.8	87	67	74.5	"	6 - 6
5-21-26	12	5	17	1	6	3.4	90	64	77.5	"	5 - 7
					Second instar						
5-25-27	200	13	66	2	6	5	89	51	75.3	Lettuce	7 - 7
5-23-27	300	12	68	2	8	5.6	85	50	71.4	"	7 - 7
5-25-27	300	12	82	5	11	6.8	87	61	78.9	"	7 - 7
5-25-27	100	9	38	2	6	4.2	87	61	78.9	Alfalfa	7 - 7
7-23-26	26	8	28	2	6	3.5	80	58	69.6	"	5 - 8
					Third instar						
6-1-27	200	13	94	3	11	7.2	87	60	79	Lettuce	7 - 7
6-2-27	300	11	71	5	8	6.4	89	61	72	"	7 - 7
6-1-27	100	9	48	3	7	5.3	87	60	79	Alfalfa	7 - 7
6-2-26	14	8	22	1	6	2.8	80	58	71	"	6 - 7
6-20-26	21	10	31	1	5	3.1	84	57	72	"	5 - 8
					Fourth instar						
6-17-27	200	10	53	1	9	5.3	83	58	74.5	Lettuce	7 - 7
6-17-27	300	11	68	1	9	6.1	83	58	74.5	"	7 - 7
6-17-27	100	9	29	1	6	3.2	83	58	74.5	Alfalfa	7 - 7
					Fifth instar						
6-30-27	200	8	41	2	10	5.2	85	58	74.2	Lettuce	7 - 7
6-30-27	300	6	30	2	9	5	85	58	74.2	"	7 - 7
6-30-27	100	5	18	1	6	3.6	85	58	74.2	Alfalfa	7 - 7
7-20-26	22	18	61	1	6	3.4	84	57	72	"	5 - 8
7-23-26	25	18	59	1	5	3.3	80	58	69.6	"	5 - 8
					Adult males (Young)						
7-20-26	23	17	55	1	6	3.2	84	57	72	"	5 - 7
7-23-26	24	17	49	1	7	3	80	60	69.6	"	6 - 8
					Adult males (Old)						
10-22-25	27	19	32	1	4	2	78	64	69.4	"	8 - 5
10-25-26	30	17	39	1	4	2.3	79	65	74	"	8 - 5
10-22-26	31	15	31	1	4	2	78	62	71.6	"	8 - 5
10-27-28	33	16	34	1	4	2.1	78	66	73.3	"	8 - 5
10-28-26	35	16	30	1	4	2	72	65	69.1	"	8 - 5
10-29-26	37	25	65	1	7	2.6	66	48	61.7	Rose Leaves	8 - 5
					Adult females (Gravid)						
10-22-26	29	20	78	1	6	3.9	78	64	69.4	Alfalfa	8 - 5
10-25-26	29	32	133	1	7	4.1	79	65	74	"	8 - 5
10-26-26	32	38	141	1	7	3.7	78	62	71.6	"	8 - 5
10-27-26	34	28	116	1	6	4.1	78	66	73.3	"	8 - 5
10-28-26	36	28	84	1	5	3	72	65	69.1	"	8 - 5
10-29-26	38	14	24	1	3	1.7	66	48	61.7	Rose	8 - 5
11-5-26	39	19	67	1	5	3.5	82	62	71.2	Four O'clock	8 - 5

Average Number of Feedings per day on lettuce 5.7.
Average of Number of Feeding per day on alfalfa 3.2.

Grasshoppers feeding on lettuce ate during a greater number of periods than those feeding upon alfalfa. This was to be expected as grasshoppers consumed greater quantities of lettuce both by weight and volume than alfalfa. The average number of periods in which feeding occurred for 559 individuals feeding under the varying temperature conditions of the experiments was 5.7 for lettuce and 3.2 for alfalfa. The maximum was 11 periods for lettuce against 7 for alfalfa. (Figure 6 gives evidence of the greater number of times feeding occurs on lettuce than on alfalfa.) The grasshoppers in this experiment were under the same environmental conditions except for food. In each case all of the grasshoppers ate during the day, but the percentage feeding each hour was much greater on lettuce than on alfalfa.

TIME UTILIZED FOR EATING

The time required, the amount eaten, the time feeding occurs and the number of individuals feeding are important factors and have a bearing on control recommendations for grasshoppers.

Studies were made to determine the total time utilized for feeding during a 1-hour period. There was considerable individual variation during any one period, as well as a variation from period to period. In a study of adult gravid females of *M. bivittatus* it was found that the time varied from 3 minutes to as much as 49 minutes and 20 seconds. For 25 grasshoppers observed the average was 16.1 minutes. There were times when feeding would not last for any noticeable length of time, the grasshoppers taking only 1 or 2 bites and not feeding further. The details of this series of experiments are shown in Table 11.

Studies were also made of nymphs ranging in age from the first to fifth instar. Grasshoppers in the above-mentioned stages varied the total time used to eat during one period from 2 to 23 minutes.

According to the above one can see that grasshoppers spend only a relatively small portion of the day feeding. To illustrate this: Take the maximum number of periods feeding occurred in any experiment, which was 7 for alfalfa and 11 for lettuce. Then allowing 16 minutes for each feeding period, one finds that in a 12-hour day with the temperature ranging between 70 and 90 degrees F. a grasshopper on lettuce spends 2 hours and 56 minutes at actual feeding, while a grasshopper on alfalfa spends only 1 hour and 52 minutes.

Table 11.—Time Utilized by Adult Gravid Females *M. bivittatus* to Eat During a 1-hour Period and Amount of Leaf Surface Consumed.

Food plant—Lettuce

Exp.	Time utilized at feeding	Time feeding began	Temp. at which feeding began	Leaf area consumed during feeding period	Date
2	3 Min.	8:45 a. m.	69 Fahr.	.31	10-22-26
1	12 " 30 Sec.	9:17 "	72 "		10-21-26
3	12 " 46 "	9:45 "	73 "	1.00	10-21-26
4	10 " 40 "	10:52 "	76 "	1.25	10-21-26
5	9 "	10:32 "	76 "	.95	10-21-26
7	7 " 45 "		70 "	1.12	10-21-26
8	14 " 15 "		70 "	1.50	10-21-26
10	49 " 20 "	8:26 "	64-69 "	.90	10-22-26
13	10 " 50 "	8:25 "	64-69 "	.64	10-22-26
17	13 " 30 "	8:20 "	64 "	.88	10-22-26
18	8 "	8:20 "	70 "	.83	10-23-26
1a	4 " 42 "	11:20 "	79 "	.41	10-25-26
2a	27 "	11:30 "		1.55	10-25-26
3a	15 "	2:30 p. m.	73 "	.80	10-25-26
22	18 " 55 "	8:20 a. m.	70 "	1.30	10-26-26
23	4 " 50 "	8:25 "	70 "	.20	10-26-26
24	3 " 20 "	8:23 "	70 "	.25	10-27-26
25	13 " 21 "	8:35 "	72 "	.91	10-28-26
26	16 " 30 "	2:20 p. m.	69 "		10-28-26
27	9 " 15 "	2:21 "	69 "		10-28-26
28	30 "	9:06 a. m.	70 "		11-3-26
29	7 " 10 "	9:05 "	70 "		11-3-26
30	5 " 25 "	9:10 "	70 "		11-3-26
31	8 "	10:30 "	78 "	.15	11-3-26
32	5 " 16 "	10:00 "	71 "	.65	11-3-26

The above figures probably vary from those that would actually be encountered in the field, but indicate the approximate time spent during a day in food consumption.

In the course of a comparatively short period grasshoppers are capable of consuming large quantities of food. For example on October 11, 1926, 1 adult female of *M. bivittatus.* was observed to eat 1.12 square inches of lettuce in 7 minutes and 45 seconds at a temperature of 70 degrees F. However, as a rule, the amount eaten in the above time is somewhat less.

A Comparison of Different Food Plants on Rate of Development

An attempt was made to gain information relative to the rate of development on different food plants. Since there was a wide variation in the amount of leaf surface eaten by the same species of grasshoppers when feeding on different plants, it occurred to the writer that this difference might cause some variation in the rate of development. Even if the dry weight food

value was the same, it appeared possible that the process of caring for the excess bulk and water might so affect the metabolic rate that a variation would occur. With this in mind 2 species of grasshoppers, *M. bivittatus*, and *M. femur-rubrum*, were selected and reared. The grasshoppers were kept under apparently identical conditions, except for food. One series was fed entirely upon alfalfa, the other entirely upon lettuce. The grasshoppers were fed daily and notes made upon moults and conditions of development. In the first experiment 12 individuals of *M. femur-rubrum* were used. In the second experiment 24 individuals of *M. bivittatus* were used. Table 12 gives a summary of the results obtained.

Table 12.—Comparison of Different Food Plants on Rate of Development.

Exp.	Average number days for each instar					Number days required for development		
	1	2	3	4	5	Max.	Min.	Ave.
			M. femur-rubrum Plant food—Lettuce					
1	10.8	10.6	9.4	12	19.6	65	59	62.4
			M. femur-rubrum Plant food—Alfalfa					
1	11.2	13.6	12.4	14.6	16.4	77	64	68.2
			M. bivittatus Plant food—Lettuce					
2	10	8.5	11	10.7	13	60	49	53.2
			M. bivittatus Plant food—Alfalfa					
2	10.5	8.5	9.5	11	15.2	64	51	54.7

At first glance it appears that the grasshoppers *M. femur-rubrum* in the first experiment developed more rapidly on lettuce than alfalfa. The average for all shows that the individuals feeding on lettuce completed 5 instars in 62.4 days while those feeding on alfalfa required 68.2 days, a difference of 5.8 days. A further study of the data shows that there was considerable overlapping in the development, so that some of the individuals feeding on alfalfa developed apparently as fast as some of those feeding on lettuce. This would indicate that there is probably little, if any, difference in the rate of development on the 2 food plants. Since there is a wide range in the rate of development of individuals, the difference could probably be accounted for in experimental error as there were only 12 individuals in the series.

This can be further illustrated by the fact that, in a series of experiments on the development of *M. differentialis* under identical food conditions and at a constant temperature of 95 degrees F., there was considerable variation in the rate of devel-

opment. All individuals of this series reached maturity in an average of 24.7 days. The minimum time required for growth was 22 days with a maximum of 32 days, thus giving a variation of 10 days.

In the second experiment, 24 individuals of *M. bivittatus* were used. The method of experimentation was the same as for the *M. femur-rubrum.* Those grasshoppers feeding on the lettuce developed thru 5 instars in an average of 53.2 days while the average for those fed alfalfa was 54.7 days, a difference of 1.5 days in favor of those fed lettuce. As in the preceding experiment, there was considerable overlapping in the rate of development. Many of the individuals feeding on alfalfa developed as quickly as those feeding on lettuce.

The average difference in the rate of development for the 2 series is small and it is entirely possible that the variation is within experimental error, or even within individual variation as has been illustrated.

THE EFFECT OF LIGHT ON DEVELOPMENT

Since all our common injurious grasshoppers are active almost entirely during daylight and are phototrophic, that is they respond toward light, one would conclude that light is essential to food consumption and development. The fact that activity in nature usually ceases when night approaches, would seem to confirm the above conclusion.

During the season of grasshopper development the hours of daylight vary to some extent. The writer, thinking this might have some effect upon development, made this study.

In an effort to determine the effect of light, if any, on the rate of development in *M. differentialis,* 2 sets of experiments of 20 grasshoppers each were begun. In experiment 1 the temperature was held to 92 to 95 degrees F., and one-half of the grasshoppers were exposed to light for 24 hours. During the night, light was furnished by a 75-watt electric lamp. The remaining one-half of the grasshoppers were given light only 12 hours during the day and then placed in complete darkness. In the second experiment the same arrangement as in experiment 1 was followed except that at night instead of being exposed to a temperature of 92 to 95 degrees F. the grasshoppers were exposed to natural temperature. The results were based on the average of those grasshoppers surviving 5 instars.

The grasshoppers in experiment 1 exposed to 12 hours of light developed thru 5 instars in an average of 23.6 days, while those exposed to 24 hours of light developed in and average of 25.1 days.

In the second experiment a reverse of the conditions of experiment 1 occurred. The insects having 24 hours of light developed in an average of 32.4 days while those exposed to only 12 hours of light developed in an average of 36 days.

Considering the number of grasshoppers in the experiment, it is entirely possible to account for the above variation by individual variation in growth. It is known that grasshoppers reared under apparently identical conditions will vary considerably in their rate of growth. Therefore, from the above results it would seem that light does not affect the rate of growth under the above-named conditions. Table 12 shows the details of the experiment.

In caring for these experiments it was observed on numerous occasions that grasshoppers would eat in complete darkness when the temperature was sufficiently high. Not only would they eat but they would also moult and grow.

Table 13.—A Study of the Effect of Light Upon the Development of *M. differentalis*.

A.—Constant temperature of 92-95 degrees F.; light for 12 hours and darkness for 12 hours.

Individual	Date hatched 1927	Moults First	Second	Third	Fourth	Fifth	Days required to develop 5th instar
1	6-3	6-9	6-13	6-17	6-21	6-27	24
3	6-3	6-9	6-13	6-16	6-23	6-29	26
7	6-3	6-9	6-14	6-17	6-21	6-26	23
9	6-3	6-9	6-13	6-17	6-20	6-26	23
10	6-3	6-9	6-13	6-17	6-21	6-25	22
Average							23.6
B.—Constant temperature 92-95 degrees F.; constant light 24 hours.							
12	6-3	6-9	6-14	6-17	6-20	6-26	23
14	6-3	6-9	6-15	6-18	6-21	6-26	23
15	6-4	6-12	6-16	6-19	6-25	7-6	32
17	6-3	6-9	6-12	6-16	6-19	6-25	22
18	6-4	6-11	6-17	6-20	6-25	7-2	28
50	5-31	6-7	6-10	6-14	6-18	6-23	23
Average							25.1
C.—Constant temperature 92-95 degrees F. 12 hours; natural temperature at night 12 hours, light 24 hours.							
22	6-4	6-11	6-17	6-21	6-27	7-4	30
23	6-4	6-11	6-17	6-22	6-27	7-4	30
24	6-4	6-11	6-17	6-20	6-26	7-2	28
25	6-4	6-11	6-17	6-20	6-26	7-4	30
26	6-4	6-11	6-17	6-21	6-26	7-6	32
1x	5-29	6-9	6-14	6-20	6-24	Lost	
2x	5-29	6-10	6-15	6-20	6-26	7-2	34
3x	5-29	6-10	6-15	6-20	6-25	7-6	38
4x	5-29	6-9	6-14	6-20	6-25	7-1	33
5x	5-29	6-9	6-14	6-20	6-26	7-5	37
Av rage							32.4

D.—Constant temperature 92-95 degrees F. 12 hours; natural temperature at night 12 hours; light 12 hours; darkness 12 hours.

30	6-4	6-11	6-17	6-22	6-27	7-15	31
33	6-4	6-11	6-17	6-23	6-29	7-22	48
38	6-4	6-11	6-17	6-21	6-29	7-7	33
39	6-5	6-12	6-17	6-23	6-29	7-7	32
Average							36

ACTIVITIES IN DARKNESS

Riley (60) states that *M. spretus* does not feed at night during cool weather, but when the weather is warm and dry it is often as ravenous during the night as during the day. He also gives evidence that there were times when flights occurred at night. He stated that Gerstaecker reported that the European *migratoria* fed mostly at night.

Usually the common injurious species of grasshoppers in Colorado exercise little or have no activity at night. They are usually found motionless in their characteristic roosting positions. Parker (54) has shown that for *Camnula pellucida* in Minnesota, this phenomenon can be correlated with temperature. He also shows that it is not a light reaction since the time when roosting begins in the field depends upon the temperature rather than the hour.

The writer in his work noticed that occasionally feeding occurred at night. As a result an experiment was started to determine the effect darkness would have upon activity.

During June, 1927, 2 series of experiments were made in which 20 second instar *M. bivittatus* were used. In one set the grasshoppers were kept in complete darkness. In the other the grasshoppers were exposed to normal conditions as afforded by daylight. Both experiments were kept under the same conditions except for light. The temperature was maintained above 70 degrees F. At the end of 24 hours the amount of food eaten was measured. Those grasshoppers kept in complete darkness consumed an average of .168 square inches of lettuce each. The maximum amount eaten by one individual was .234 square inches and the minimum amount was .058 square inches. Those individuals fed under normal light conditions ate an average of .139 square inches of lettuce, with a maximum of .124 and a minimum of .093 square inches.

This indicates that when the temperature is within the range of activity a grasshopper will eat in darkness and at night as well as in the daylight. Numerous other observations in which comparisons were not made bear out this conclusion.

Another test was made in which grasshoppers were reared in complete darkness except for the few minutes each day that

was required to place food in the cage. It was found that *M. bivittatus* will eat, grow and moult when kept in complete darkness. No extensive comparisons were made of the effect that darkness had on the rate of development but preliminary comparison was made between the first and second moults. The series given normal conditions required an average of 11.6 days to pass from the first to the second instar. The maximum number of days was 14 and the minimum 9 days. Those kept in darkness averaged 10.1 days with a maximum of 13 days and a minimum of 9 days. This would indicate that the rate of development was about the same. Elsewhere in this paper it is shown that the rate of development is essentially the same under continuous light as it is under intermittent darkness of 12 hours and light 12 hours. This would tend to further confirm the above. Temperature records were not kept over the entire period of the experiment but the grasshoppers completed their growth in an average period of 67 days.

According to these results it appears safe to predict that under favorable conditions grasshoppers will eat and cause losses during the entire 24 hours of the day. However, in Colorado, with its cool nights, grasshoppers do not normally feed during the entire night. Feeding probably occurs only during those hours of the night when the temperature is above 68 degrees F.

ECONOMIC ASPECTS OF THE RESULTS

An analysis of results obtained in this research indicates that the following factors are of economic importance:

Temperature is an important factor in reproduction, development and feeding habits. These activities are closely associated with the economic status. High mean daily temperatures are conducive to rapid development, which indicates that if other weather conditions are favorable a year with a combination of an early spring, hot summer and late fall is ideal for grasshopper development and maximum damage. Such conditions would cause early hatching of eggs as well as early maturity of the insects. Further, these conditions make maximum losses possible not only from the nymphs but from the adults, due to the favorable days which permit a long period over which feeding can occur. Egg production would also be at its maximum which would favor an outbreak the following year.

Since adults eat almost 100 times as much in a day as first instar nymphs, grasshoppers should be poisoned when they are in the nymphal stage. Poisoned bait should be applied during the period when activity is confined to the surface of the ground.

Bait should not be applied during specified hours, but only during those hours in the day, when the ground temperature is at least 68 degrees F. and less than 100 degrees F. After the ground temperature goes above 98 degrees F. poison should not be applied since grasshoppers have a tendency to climb vegetation and other debris to a comfortable temperature. After the grasshoppers leave the ground they do not feed on the bait on the soil surface but upon the vegetation on which they rest.

It would appear that the efficiency of the bait is determined by the number of hours that it is comfortable for the grasshoppers to feed at the surface of the ground. If the ground-feeding period is relatively short and universal feeding does not occur, control results are not apt to be as satisfactory as when this period is longer.

The morning hours are most desirable for the application of baits since at that time the ground-feeding periods are longest. The bait should be on the ground by the time the surface temperature reaches 68 or 70 degrees F. in order to permit as many grasshoppers as possible to feed upon it.

If bait is applied after the first general feeding period of the day is completed, the chances are that a high mortality will not be obtained due to the fact that the feeding periods of grasshoppers are of short duration. Moreover, the insects feed only during a small number of periods in the course of a day. This is regulated by the temperature and character of the food plant, altho the kind of food plant is likely to have an indirect bearing on the results obtained. For example, if the food is lettuce the chances should be greater for a high mortality than if the food is alfalfa because grasshoppers eat more often when feeding upon lettuce than on alfalfa. Thus the opportunities for being poisoned are increased.

When the insects are in the nymphal stage it appears that moulting may at times be a factor responsible for ineffective kills. Under ordinary conditions 1 to 2 days are lost during the moulting process. If a field containing nymphs of approximately the same age be poisoned during the moulting period, it is likely that a markedly inefficient kill will be obtained. It is known that all grasshoppers hatched on the same day do not moult at uniform periods, but if only 25 percent moulted on the same day the results in control might be very noticeable.

The species infesting a field will make a difference in the actual losses to the grower. *M. bivittatus* and *M. differentialis*, eat almost twice as much per day as *M. femur-rubrum*. Therefore an infestation of one of the larger species which equals in

numbers the smaller species will cause twice the loss of the smaller species.

If the temperature is sufficiently high, losses will occur during both day and night. Light appears to have no affect on feeding.

BIBLIOGRAPHY

(1) Abbe, Cleveland
1878. Thermal Constant for Locust Eggs. First Report of the U. S. Ent. Comm. 426-432.

(2) Abbe, Cleveland
1905. The Relation Between Climate and Crops. U. S. Weather Bureau, Bul. 36.

(3) Bachmetjew, P.
1901. Experimentelle Entomologische Studien, I. Temperatur Verhaltinisse Bei Insekten. 160. Leipsig 1901.

(4) Ball, E. D.
1915. How to Control the Grasshoppers. Utah Agr. Col. Exp. Sta. Bul. 138.

(5) Back, E. A., and Pemberton, C. E.
1916. The Effect of Cold-Storage Temperatures on Pupae of the Mediterranean Fruit Fly. Jour. Agr. Res. 6: 251-260.

(6) Bodine, Joseph Hall
1921. Factors Influencing the Water Content and the Rate of Metabolism in Certain Orthoptera. Jour. Exp. Zool. 32: 137-264.

(7) Bodine, J. H.
1925. The Effect of Temperature on the Rate of Embryonic Development of Certain Orthoptera. Jour. Exp. Zool. 42: No. 1.

(8) Chapman, R. N.
1926. Insect Ecology.

(9) Claassen, P. W.
1915. Grasshoppers of Kansas. Univ. of Kan. Bul. Biol. Series, Vol. 18, No. 1.

(10) Cooley, R. A., Parker, J. R., and Seamans, H. L.
1918. Grasshopper Control in Montana. Mont. Agr. Exp. Sta. Cir. 76.

(11) Cook, Wm. C.
1927. Some Effects of Alternating Temperatures on the Growth and Metabolism of Cutworm Larvae. Jour. of Econ. Ent. Vol. 20, No. 6: 769-782.

(12) Cooley, R. A., Parker, J. R., and Strand, A. L.
1923. Improved Method of Controlling Grasshoppers. Cir. 112, Mont. Agr. Exp. Sta. 1-20.

(13) Corkins, C. L.
1921. Grasshopper Control. Colo. Ext. Bul. Series 1, No. 180-A.

(14) Corkins, C. L.
1923. Grasshopper Control in Colorado. Bul. 287, Colo. Agr. Exp. Sta. 3-19.

(15) Corkins, C. L.
1923. Sodium Arsenite as a Killing Agent in Grasshopper Baits. Bul. 280, Colo. Agr. Exp. Sta. 3-15.

(16) Cotton, E. C., and Voorhees, J. F.
1911. The Cattle Tick as Affected by Climate. Tenn. Agr. Exp. Sta. Bul. 94.

(17) Criddle, Norman
1920. Locust Control in the Prairie Provinces. Canada Dept. of Agr., Ent. Branch, Cir. 13.

(18) Davis, J. J.
1919. The Value of Crude Arsenious Oxide in Poison Bait for Cutworms and Grasshoppers. Jour. of Eco. Ent., Vol. 12: 200-203.

(19) Davis, J. J.
1919. Grasshopper Control in Indiana. Ind. Purdue Cir. 88.

(20) Dean, G. A.
1911. Heat as a Means of Controlling Mill Insects. Jour. Ec. Ent. 4: 143-158.

(21) Fere, C.
1894. Note sur L'influence de la temperature sur L'incubation de L'eouf de Poule. Jour. de L'anat et de la Physical. 30: 352-265.

(22) Flint, W. P.
1919. Method of Destroying Grasshoppers. Ill. State Nat. His. Sur., Nat. Series, Cir. 3.

(23) Flint, W. P.
1920. Poison Bait for Grasshoppers. Jour. of Ec. Ent. Vol. 13: 232-236.

(24) Fluke, C. L., Jr.
1921. Poison the Grasshoppers. Wis. Ext. Cir. 135. 2-4.

(25) Ford, A. L.
1921. The Effect of Poison Bran Mash on Grass-

hoppers and the Lapse of Time Between Poisoning and Death. Jour. of Ec. Ent., Vol. 14: 281-285.

(26) Ford A. L., and Larrimer, W. H.
1921. Observations on the Attractiveness of Materials Used in Grasshopper Baits. Jour. Ec. Ent., Vol. 14: 285-291.

(27) Ford, A. L., and Larrimer, W. H.
1921. Some Factors Influencing the Efficiency of Grasshopper Baits. Jour. of Ec. Ent. Vol. 14: 292-299.

(28) Ford, A. L., and Larrimer, W. H.
1922. The Daily Maximum Feeding Period of *Melanoplus femur-rubrum.* Canadian Ent. Vol. LIV No. 6: 141-143.

(29) Fry, H. J.
1927. Grasshopper Culture in the Laboratory. Jour. N. Y. Ent. Sec. Vol. 35, No. 1: 41-51.

(30) Granovsky, A. A.
1925. The Organized Co-operative Campaign Against Grasshoppers in Wisconsin. Jour. of Ec. Ent. Vol. 18: 73-83.

(31) Hartzell, F. Z.
1919. Comparison of Methods for the Computation of the Daily Mean Temperatures. Effect of Discrepencies Upon the Investigations of Climatologists and Biologists. N. Y. Agr. Exp. Sta. Bul. 68 (Tech.)

(32) Headlee, T. J.
1914. The Effect of Temperature and Moisture on the Rate of Insect Metabolism. Jour. Econ. Ent. 7: 413-417.

(33) Headlee, T. J.
1917. Some Facts Relative to the Influence of Atmospheric Humidity on Insect Metabolism. Jour. Econ. 10: 31-38.

(34) Herrick, G. W., and Hadley, C. H., Jr.
1916. The Lesser Migratory Locust. Cornell Bul. 378.

(35) Hopkins, A. D.
1900. Hessian Fly in West Virginia. West Va. Agr. Exp. Sta. Bul. 67: 242-243.

(36) Hopkins, A. D.
1918. The Bioclimatic Law. Sci. Monthly, 8: 496-513.

(37) Howard, L. O.
1896. Some Temperature Effects on Household Insects. U. S. Dept. of Agr. Div. Ent. Bul. 6, n.s. 13-17.

(38) Hunter, W. D.
1908. A Tentative Law Relating to the Incubation of the Eggs of the Cattle Tick. Jour. Econ. Ent. 1: 51-55.

(39) Kramer, S. D.
1915. Effect of Temperature upon the Life Cycle of *Musca Domestica* and *Culex Pipiens*. Science, n.s. 41: 874-877.

(40) Krogh, August
1914. On the Rate of Development and Carbon Dioxide Production of Chrysalides of *Tenebrio Moliter* at Different Temperatures. Zeitscher. fur allgem. Physiol. 16: 178-190.

(41) Larrimer, W. H.
1921. Grasshopper and Cricket Repellents. Jour. of Econ. Ent. Vol. 14: 259-263.

(42) Loeb, J., and Northrup, J. H.
1917. On the Influence of Food and Temperature upon the Duration of Life. Jour. Biol. Chem. 32: 103-121.

(43) Margulus, S.
1924. Effects of Environmental Temperature on Metabolism. Am. Jour. Phys. 71: 49-59.

(44) Milliken, F. B.
1915. Grasshoppers and Their Control on Sugar Beets and Truck Crops. U. S. D. A. Farmers' Bul. 691: 3-20.

(45) Morrill, A. W.
1918. Experiments with Grasshopper Baits with Incidental Observations on the Habits and Destructiveness of the Differential Grasshopper *(Melanoplus differentialis)*. Jour. of Econ. Ent. Vol. 11: 175-181.

(46) Morrill, A. W.
1919. The Value of Molasses and Syrups in Poisoned Baits for Grasshoppers and Cutworms. Jour. of Econ. Ent. Vol. 12: 337-343.

(47) Morse, W. P.
1920. Orthoptera of New England. Proceedings Boston Society Natural History. Vol. 35, No. 6.

(48) Peairs, L. M.
1914. The Relation of Temperature to Insect Development. Jour. Econ. Ent. 7: 174-179.

(49) Peairs, L. M.
1927. Some Phases of the Relation of Temperature to the Development of Insects. West Va. Agr. Exp. Sta. Bul. 208: 3-53.

(50) Pettit, R. H.
1924. Common Pests of Field and Garden Crops. Grasshoppers. Spec. Bul. 132. Mich. Agr. Exp. Sta. 3-4.

(51) Pierce, W. Dwight
1916. A New Interpretation of the Relationships of Temperature and Humidity to Insect Development. Jour. Agr. Res. 5: 1183-1191.

(52) Parker, J. R., and Seamans, H. L.
1920. Experiments with Grasshopper Baits. Jour. of Econ. Ent. Vol. 14: 138-141.

(53) Parker, J. R.
1922. Improvements in the Methods of Preparing and Using Grasshopper Baits. Bul. 148, Mont. Agr. Exp. Sta. 3-19.

(54) Parker, J. R.
1924. Observations on the Clear Winged Grasshopper. Bul. 214, Minn. Agr. Exp. Sta. 5-44.

(55) 1926. Why Grasshoppers Increase in Numbers Some Years. 32nd Annual Rept. Mont. Exp. Sta.

(56) Rehn, J. A. G., and Hebard, M.
1908. Proc. Acad. Nat. Sci. Phila. 365.

(57) Rehn, J. A. G., and Hebard, M.
1909. Proc. Acad. Nat. Sci. Phila. 111.

(58) Richardson, C. H.
1925. The Oviposition Response of Insects. Bul. 1324, U. S. Dept. of Agr.

(59) Ricker, D. A.
1919. Experiments with Poison Baits Against Grasshoppers. Jour. Econ. Ent. Vol. 12: 194-200.

(60) Riley, C. V.
1877. The Rocky Mountain Locust. First Annual Rept. of the Entomological Commission.

(61) Riley, C. V., Packard, A. S., and Thomas, Cyrus.
1880. The Rocky Mountain Locust. Second Report U. S. Entomological Commission.

(62) Rockwood, L. P.
1925. On Night Flying and Attraction to Light in Acrididae and the Relation of Meteorological Conditions Thereto. The Pan-Pacific Entomologist Vol. 2, No. 1: 36-38.

(63) Ruggels, A. G., and Parker, J. R.
1924. Kill Grasshoppers with Poisoned Bran Mash. Minn. Agr. Ext. Cir. 17.

(64) Sanderson, E. Dwight
1908. The Relation of Temperature to the Hibernation of Insects. Jour. Econ. Ent. Vol. 1: 56-65.

(65) Sanderson, E. Dwight
1908. The Influence of Temperature in the Northern Distribution of Insects. Jour. Econ. Ent. Vol. 1: 245-262.

(66) Sanderson, E. Dwight
1910. The Relation of Temperature to the Growth of Insects. Jour. Econ. Ent. Vol. 3: 133-140.

(67) Sanderson, E. Dwight, and Peairs, L. M.
1914. The Relation of Temperature to the Development of Insects. N. Hamp. Agr. Exp. Sta. Tech. Bul. 7.

(68) Schweralla, Alphonse M.
1924. Influence of Temperature on Rate of Locomotion Amoeba. Jour. Morph. 39: 465-514.

(69) Severin, H. H. P., and Severin, H. C.
1910. The Effect of Moisture and Darkness on the Emergence from the Egg of the Walking Stick, *Deapheromera feorata, Say.* Jour. Econ. Ent. 3: 479-481.

(70) Severin, H. C., and Gilbertson, G. I.
1917. Grasshoppers and Their Control. So. D. Bul. 172.

(71) Shelford, V. E.
1926. An Experimental Investigation of the Relation of the Codling Moth to Weather and Climate. Ill, Nat. Hist. Surv. Bul. 16, Art. 5.

(72) Shreve, Forrest
1914. The Role of Winter Temperatures in Determining the Distribution of Plants. Am. Jour. Bot. 1: 194-202.

(73) Smith, H. E.
1915. The Grasshopper Outbreak in New Mexico

During the Summer of 1913. U. S. D. A. Bul. 293.

(74) Somes, M. P.
1914. The Acrididae of Minnesota. Minn. Agr. Exp. Sta. Bul. 141.

(75) Strand, A. L.
1925. Leaflet, Mont. Agr. Exp. Sta. 1-4.

(76) Swenk, M. H.
1917. Emergency Entomological Service. Nebr. Cir. No. 7: 14.

(77) Swenk, M. H., and Wehr, E. E.
1923. Experiments with Poisoned Baits for Grasshoppers. Nebr. Agr. Exp. Sta. Bul. 183: 2-28.

(78) Swenk, M. H.
1927. Further Experiments with Poisoned Baits for Grasshoppers. Neb. Agr. Exp. Sta. Bul. 41.

(79) Thomas, Cyrus
1879. Relation of Temperature to the Development of (Locust) Eggs. Second An. Rept. U. S. Ent. Comm. Chap. 5.

(80) Urbahns, T. D.
1919. Grasshoppers and Control Measures. Calif. Mo. Bul. Dept. Agr. Vol. 8, No. 9.

(81) Uvarov, B. P.
1923. Some Problems on the Biology of the Grasshopper. Males des Epiphytes, Vol. 9, No. 2: 87.

(82) Walton, W. R.
1920. How to Detect Outbreaks of Insects and Save the Grain Crop. U. S. D. A. Farmer's Bul. 135: 16.

(83) Henry, W. A., and Morrison, F. B.
1922. Feeds and Feeding. Henry Morrison Company, Chicago.

(84) Sherman,
Chemistry of Food and Nutrition. The Macmillan Company.

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OUTLINE OF COLORADO TAX LAWS
FOR FARMERS AND RANCHMEN

By G. S. Klemmedson
and C. C. Gentry

In Cooperation with Division of Finance,
Bureau of Agricultural Economics, U. S. D. A.

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*On leave, 1929

TABLE OF CONTENTS

PREFACE

The primary purpose of this tax guide is to place in the hands of farmers and ranchmen tax information that is most often used so that they may know their duties, rights, and privileges in regard to general taxation.

It is not intended to give the full text of the tax laws, but simply to give a summary of selected portions. Many Colorado farmers and ranchmen are not aware of the provisions safeguarding their rights and therefore fail to protest against certain injustices and unintentional mistakes. Failure to make a protest at the proper time places the responsibility for unjust and excessive taxation upon the taxpayer himself.

The assessment, levy, collection of taxes, and sale of property for taxes is entirely governed by law and court decisions and it is well to have at least a knowledge of the fundamentals. Taxes should be levied without favoritism for any special group and with full justice for all classes.

The county assessor and treasurer or your local attorney will always be glad to give you information in regard to your tax problems.

Attention is called to several recent publications on taxation problems in Colorado as follows: Don C. Sowers, "The Tax Problem in Colorado," University of Colorado Bulletin, Vol. XXVIII, No. 12 General Series No. 261, Boulder, Colorado, 1928; "The Problem of Over-appropriation and the Public Bonded Indebtedness of Colorado," Colorado State Teachers College Bulletin, Series XXVIII, No. 8, Greeley, Colorado, 1928; Whitney Coombs, L. A. Moorhouse, and Burton D. Seeley, "Some Colorado Tax Problems," Bulletin 346, Colorado Agricultural Experiment Station, Fort Collins, Colorado, 1928.

)UTLINE OF COLORADO TAX LAWS

FOR FARMERS AND RANCHMEN

BY G. S. KLEMMEDSON AND C. C. GENTRY

Levying Taxes

Taxes take about 30 percent of the farmers' net in- ome so it is only natural for the average farmer to in- uire as to how his tax money is spent, whether the cost f the service he demands is fairly distributed, and 'hether he is getting his money's worth for what he ays. Farmers receive not more than 25 percent of Col- rado's income and pay approximately 35 percent of the ax.

What are the sources of revenue in Colorado?

Seventy percent of the revenue is obtained from the eneral property tax. Thirty percent is obtained from he following sources of revenue: 4-cent gas tax; motor- ehicle license fee; inheritance tax; 2 percent of annual isurance premiums; corporation annual franchise tax; usiness and non-business licenses; metal-mining fund; unting and fishing licenses; income from state lands; rants from the federal government; and miscellaneous inds from state departments and institutions.

Why are taxes levied?

The increasing expansion in local government activi- es and expenditures is due to the fact that taxpayers emand more and better schools, highways, hospitals and ther public services of all sorts. The annual tax on the 'ealth of Colorado is for the purpose of providing for iese services, furnished for our benefit and protection y the state, county, school district, city and town.

Who can tax?

Colorado has delegated by constitutional and statu- ory enactment the power to levy taxes under certain con- itions and for certain purposes. (Art. 10 State Const.)

State tax

Taxes for state purposes are provided by the gener- assembly and levied by the State Board of Equaliza- on. This levy may not exceed 5 mills on the dollar, 1 ill of which may be used for the purpose of educational uildings at the discretion of the general assembly. 7367) (Art. 10, Sec. 2 and 11, State Const.)

County tax

County commissioners levy taxes for the purpose of aying county expenses of different kinds such as the

ote: The number after each paragraph refers to sections in Com- ed Laws of Colorado—1921, Session Laws, or Articles in the State nstitution.

paying of outstanding warrants and other indebtedness (not to exceed 5 mills on the dollar); for the erection and maintenance of buildings; for roads and bridges; bonds and interest; mothers' compensation (not to exceed one-eighth mill); for the poor; and for school purposes. The power of levy is limited to certain mill levies based on the assessed valuation of the county as prescribed by sections 7204 to 7214, and 1246 of the Compiled Laws of Colorado, 1921. For example, section 1246 states that county commissioners may levy a property tax for road purposes which shall not exceed one dollar on each $100 to be levied and collected in the same manner as other property taxes. (7204) (8665) (7457)

General school fund

The county commissioners annually levy a tax (not to exceed 5 mills), for the purpose of paying teachers' salaries. (8448) (8449) (8450) (Chap. 159, Ses. Laws, 1927)

Teachers' retirement fund in first-class districts

Money for the use of teachers' retirement fund may be secured by a special levy (not to exceed one-fifth of one mill), upon the property in first-class school districts. (8459)

County and union high schools

The county commissioners may levy a tax (not to exceed 4 mills), for the maintenance of the high school in any district except in the case of union high schools in fourth or fifth-class counties, that is, counties with the smallest population, in which case the mill levy shall not be less than 1 mill or more than 3 mills. (8411) (8412) (8392) (8383)

Special school tax

The school board in each district shall levy special taxes, not to exceed 20 mills, for the purpose of maintaining the district schools. A portion of this levy, not exceeding one-tenth of a mill, may be used for the purchase of library books. (8286)

City and town tax

City or town taxes are levied by city or town officials on real and personal property in accordance with laws of the state. No tax may exceed the previous year's levy by more than 5 percent. (See section on limitations of taxing bodies.) (9149, 7214, Art. 10, Sec. 7, State Const.)

Assessor and treasurer not responsible for making tax levies

It is the duty of the assessor to figure the amount of tax on the property as assessed after the levies are certified by the several boards. The asssessor's office has nothing to do with making the levies, and his responsibility ends with the assessment of property. The county treasurer acts only as a collector of taxes.

The legislature of Colorado has provided certain ximum rates of taxation for certain purposes which y not be exceeded by the local governments (county, ool districts, cities or towns), except for the payment bonds and interest thereon, judgments or assessments; d has stipulated, in addition, that no tax levy in any ar may exceed the previous year's levy by more than percent. (7214, Article XI, State Const.)

Limitation to increased levies of taxing bodies

But if any board of levy or any officer charged with ch duty is of the opinion that the amount of tax, thus ited by law, is insufficient for the needs of the taxing trict for the current year, the question may be submit- l to the State Tax Commission. (Compiled Laws of 21, Sec. 7216)

Tax Commission may authorize a needed increase in tax levy of 5 mills

If upon examination the State Tax Commission finds t an increase over the limits prescribed by law is jus- ed, it may recommend such levy, and the taxing dis- ct is thereby authorized to increase the levy by a max- um additional 5 mills.

If the State Tax Commission refuses or fails to rec- mend an increase or if the additional 5-mill levy per- tted proves insufficient, the question may then be sub- tted to the voters. If approved by three-fourths of se voting, the levy becomes legal and the officers of local government may make the extension on the tax ls.

The question of tax increase may be submitted to voters

Assessment of Real and Personal Property

Who Can Be Taxed?—Every taxable inhabitant and rporation shall make and deliver to the assessor be- een April 1 and May 20 in each year a sworn statement all taxable property of which he was the owner on ril 1 of the current year. (7225) (Art. 10, State nst.)

Taxpayer must make a sworn statement of taxable property between April 1 and May 20

A demand from the assessor for the return of taxa- property is unnecessary. Any person not owning perty must return the blank with a statement to that ect. In other words, it is up to the individual taxpay- to see to it that his property is assessed if he wishes avoid the penalties. (7371)

Every person shall also at the same time make a sep- te sworn statement of all taxable property held, pos- sed or controlled by him (as an executor, administra-

tor, guardian, trustee, receiver, partner, agent, offic or representative) for the use of another. (7234, 740

Penalty for failure to return schedule

Any person who wilfully fails, neglects or refuses return a schedule, or who returns a schedule known be incorrect or defective, is liable to a fine of not mo than $1,000. (7251)

The assessor, however, is not bound to rely entire upon the sworn statement of the taxpayer but shall d termine for himself the value of each item.

Taxable property defined

What Things Are Taxed or Can Be Taxed?—Taxab property includes real property, personal property, right credits and all tangible property. Where any property mortgaged, or pledged for security of a loan or debt, th borrower is assessed on the full value of the propert and the lender is exempt. Any such secured notes, mor gages, deeds of trust contract or conveyance shall not b assessed. (7195)

Real estate

Real estate includes all land or interests in lan within the state to which title or right to title has bee acquired; all equities in state and school lands purchase under contract, all mines, minerals, quarries, all right and privileges belonging thereto, and such improvement as buildings, water rights, structures, fixtures and fence (1178, 7193)

Personal property

Personal property includes everything which is su ject to ownership, whether tangible or intangible, an which is not included in real estate; for example, furn ture, livestock, automobiles, radios, agricultural impl ments, money and notes.

Credits include claims and demands for money, l bor or other valuable thing, and annuities. Pensions fro the United States, and salaries expected for services be rendered are not included.

Intangible property

Intangible property includes rights, credits, fra chises, special privileges and special advantages havi a value; for example, mineral rights, corporation a bank stock, mortgages, bonds, bank deposits and open a counts.

Livestock driven into county for grazing purposes is subject to taxation

In What Ways and to What Extent Can Men Things Be Taxed?—If livestock grazes in two counti the taxes shall be divided between the counties accordi to the portion of the year they are grazed in the counti (7461)

All livestock imported into the state and fattened on gricultural products grown wholly or partially within ne state shall be valued for taxation at such proportion f their full cash value as the time they are within the ate bears to the full year and shall be assessed whether ney are in the state upon the first day of April or not. 7462)

Feeders brought into state and fattened are subject to tax in proportion to the time in state

When Is Personal Property Listed and Assessed?— All taxable property must be listed and valued each ear. Personal property is listed and assessed April 1. 7178, 7249)

Personal property is listed and assessed April 1

Classes of Property Exempt From Taxation.—Peronal property of every person being the head of the famy, to the value of $200, is exempt. (7198)

Personal property valued under $200

Canals, ditches and flumes owned and used by indiduals or corporations for irrigating land owned by such ndividuals or corporations cannot be separately taxed rom the land on which the water is used. (7198, 7199)

Ditches are free from tax where no revenue is derived from same

Land incapable of being irrigated and cultivated inuded within an irrigation district is not subject to taxion for irrigation district purposes. (Amend. to Sec. 995 and 2082, Chap. 119 and 120 Ses. Laws of Colorado, 927)

Property of drainage and irrigation districts is exnpt from taxation. (1972, 2069, 2134)

The increase in value of private lands caused by the anting of timber, other than fruit trees and hedges, hall not, for a period of 30 years from the date of plantg, be taken into account in assessing such lands for taxion. (7201)

Timber planting exempt for a period of 30 years

The increase in value must be taken into consideraon in assessing the property, in the event that any such mber becomes mature or suitable for economic use prior the expiration of the 30 years. (7202)

Timber subject to tax at maturity

Fair associations are exempted when and while their roperty is actually and exclusively used for fairs not opated for pecuniary profit. (7203)

Fair associations are exempt

The property, real and personal, bonds or other seirities of the United States, the state, counties, cities, wns and other municipal corporations and public libraes, are exempt from taxation. (Art. 10, Sec. 4, State onst.)

Public property

Charitable societies, churches, schools

Fraternal benefit societies organized as charitable o benevolent institutions, property used for religious pur poses, or schools not conducted for profit, are exemp from taxation. (7198, 2630) (Art. 10, Sec. 5, State Const.

Debts secured by property are totally exempt

Shares of stock, except bank stock, and debts secur ed by property in the state are exempt from taxatio (7195, 7383)

Debts may be deducted from credits only

In listing the amount of notes and credits held b him, each person is entitled to deduct from his notes o credits all his debts from the value of the amounts, bu not including any liability to any insurance company fo premiums on policies, or subscriptions to societies, or fo the purchase of any bonds, treasury notes or other secu ities of the United States not taxable, or other exemp property. (7236)

A statement of indebtedness for which deduction i claimed, must be given. Such statement is to be kept co fidential by assessor. (7237, 7240)

When erroneous or excessive assessments occur, persons may apply to assessor

If any person believes that his property has not bee assessed according to the provisions of the law he ma appear before the assessor and make known the facts i the case, and if assessment is erroneous under the lav the assessor shall correct the same. The assessor mus give owner notice before the first Tuesday in August tha he will hear any and all objections to the assessment ro (7291, 7447)

County board of equalization hearings first Tuesday in September

County commissioners constitute a board of equal zation to equalize assessments among taxpayers. Hea ings are held the first and third Tuesday in Septembe (7458)

Objections when the value is less than $7500

When the amount of total assessed valuation in di pute is less than $7500, the taxpayer may appeal from th assessor's decision in writing to the board of county con missioners before the first Monday in January followi the assessment. (7293, 8702, 7447)

In case the county commissioners refuse the petitio the taxpayer may appeal the decision to the district cou on written notice within 30 days. The taxes must be pa before this appeal will be allowed. Rebates made by cou ty commissioners must be approved by the tax commi sion. (7460) (8702)

When the valuation exceeds $7500 the taxpayer ma appeal to the district or county court before the first Mo day in January following assessment. (7292)

The State Tax Commission may receive complaints nd carefully examine into all cases where it is alleged hat property subject to taxation has not been assessed r has been fraudulently or for any reason improperly or nfairly assessed, or the law in any manner evaded or viated, and may cause to be instituted such proceedings s will remedy improper or negligent administration of he taxation laws of Colorado. A taxpayer may file a petion with the Colorado Tax Commission before August 25 n appeal from county commissioners. (7334, 7335, 7336, 287, 7460, 8702)

Tax commission to see that all tax laws are obeyed and may receive and examine complaints where tax is incorrect

On account of the frequent changes of ownership of roperty, it is often assessed under some other name than hat of the person liable for taxes or listed as "owners unnown." The only way an individual can be sure that he properly assessed therefore, is to furnish the assessor ith an accurate legal description of his property—secon, township, range, lot and block numbers—and the ame of the addition in which it is situated. It is the du- of every property owner to return his schedule to the ssessor each year, and to see that the property is proprly described. When this duty is neglected, confusion nd over-assessments frequently occur, and the blame ests entirely upon the property owner. (7256, 7257, 7178 370)

Listing and assessment where owner is unknown

If any property is omitted from assessment for any ear or series of years, when discovered it shall be asessed for all arrearage of taxes. (7321)

Omitted property taxed for arrears

Collection of Taxes

The previous year's taxes are due January 1.

Taxes may be paid in two equal payments. To avoid enalties, the first half must be paid prior to March 1, nd the second half must be paid prior to August 1, Amend. Sec. 7191, Ses. Laws 1925, 1927)

First half of tax is due before March 1, the remainder before August 1

From March 1 to December 1 the first half bears inerest at the rate of 10 percent per annum.

Penalties for delinquent tax

All unpaid taxes become delinquent August 1 and ear interest thereafter at the rate of 10 percent per anum until the property is sold. If the entire tax due for he year is paid by May 1 no penalty will be attached.

All taxes on property remain a perpetual lien until paid

A legal claim or charge on property for current taxes is attached April 1 on all real and personal property and remains a continuous lien or claim upon the property until all taxes are paid. (7180, 7375)

Taxpayer may recover an illegal or erroneous tax which he has paid

The taxpayer has the right to recover or collect from the county an illegal tax or tax collected by mistake which he has paid, altho rebates must be approved by the tax commission. (7447, 7460, 7335, 1179, 7287)

Taxpayers should keep receipts as evidence of tax payments

A treasurer's record of receipt is received in al courts as evidence of payment and taxpayers are cautioned to keep them in a safe place for a period of years (7372, 7373)

Who pays the tax when land is bought or sold?

When there is no expressed or written agreement as to which shall pay the taxes on land conveyed, the buyer must pay the taxes for the year in which the sale is made if land is purchased before the first of July; if sold after the first of July the seller must pay the taxes for the year. Irrigation taxes also come under this section (7399)

Sale of Real Estate Delinquent for Taxes

Treasurer shall notify owner of delinquent tax

The county treasurer shall, after the first of August and before the first of September in each year, notify by mail at their last known address each person by whom taxes for the previous year are unpaid. The treasurer shall allow 10 days for the property owner to make payment. After 20 days the treasurer shall notify owner by mailing notice describing land to be sold. Land cannot be listed or sold before September 1. (7402, 1999)

Notices that taxes are unpaid and delinquent are published in four consecutive weekly issues of the loca paper, or if in a daily newspaper, only four times, once each week, prior to sale, or posted near door of treasurer's office. (7403, 7405, 5397) (Chap. 161, Ses. Laws o Colorado, 1923)

Time and place of sale of property for delinquent tax

Property is advertised for sale for delinquent taxe on or about November 1. The sale begins on or about December 1 and is held at the treasurer's office. (7409 (Amend. to 7410 and 7411, Chap. 148, Ses. Laws, 1925)

After land has been sold 3 years for taxes, the purchaser on presentation of certificate, may receive deed for land

At the end of 3 years from the date of sale of any land for taxes, the purchaser on presentation of a certificate of purchase and proof of compliance with the law may receive a tax deed. (7422, 7425)

Redemption of Real Estate Sold for Delinquent Taxes

Real property sold for taxes may be redeemed by the wner, or agent at any time before the expiration of 3 ears from the date of sale, or thereafter at any time be- ore the execution of the treasurer's deed to the purchas- r, by the payment of the amount for which it was sold, ith interest from the date of sale. (Amend. to 7430, hap. 148, Ses. Laws, 1925)

Property sold for tax may be redeemed within 3 years or before the execution of the treasurer's deed by paying tax with interest

When property is sold for taxes, the amount for hich the same is sold draws interest from the date of ale at the rate of 18 percent per annum for the first 6 onths, and 12 percent per annum for the next 30 onths, and 8 percent per annum thereafter until re- eemed, provided, the purchaser of the property has not id in the same at a lower rate of interest than that pro- ided by law.

The charge for advertising is 40 cents for each de- cription of lands, and 20 cents for each description of wn lots.

The land of minors or any interest they may have in ny lands sold for taxes may be redeemed at any time efore such minors become of age and during 1 year ereafter. (7431)

Land of minors may be redeemed before they become of age or within 1 year thereafter

Action for the recovery of land sold for tax must be ade within 5 years after the execution and delivery of e deed, except in the case of minors or insane persons. Amend. Sec. 7429, Chap. 148, Ses. Laws, 1925)

Action to recover land must be made within 5 years

Land sold when owned by two may be redeemed by e paying a proportional amount. (7434)

A party of an undivided estate or farm may redeem e part by paying his proportionate part. (7436)

If a mortgagor fails or neglects to pay the taxes, or ermits any lands so mortgaged to be sold for taxes, the ortgagee may pay the taxes or redeem the land sold for xes, and any taxes so paid shall be a lien on the land ntil paid. (7400)

Holder of a mortgage can pay taxes and redeem land sold for taxes

Laws Relating to Motor Vehicle and Gasoline Taxation

The annual license fee on automobiles is one-half of percent of the original factory cost with a minimum fee $5.00 with a reduction of 30 percent in the fee after e fifth year, and 50 percent reduction after the eighth ear. (Chap. 149, Ses. Laws, 1923)

Automobile and truck licenses

Licenses on trucks vary from $10 to $50 for the first 5 tons, and $25 per additional ton. (1341)

Registrations made after May 1 and prior to October 1, pay three-fourths of the full annual fee; and registrations made after October 1, pay one-fourth of the annual fee. (1339)

All registrations expire on December 31 and a new license must be obtained before January 1. Application for a new license can be made from November 15 to January 1.

Gasoline tax of 4 cents a gallon for roads

All persons using motor vehicles on the streets or highways are required to pay a tax of 4 cents a gallon on gasoline. (House Bill 529, 1929, to repeal Chap. 140, Ses. Laws, 1927)

Gasoline used in tractors, etc., exempt

Farmers who use gasoline for other purposes than the propelling of motor vehicles on public streets or highways are entitled to a refund by the state treasurer on application to the state inspector of oils within 60 days after the purchase, when supported by an affidavit and when accompanied by the original paid invoice or sales receipt. The application must be made on forms prescribed and furnished by the state inspector of oils.

The Inheritance Tax

In 1927 the legislature of Colorado revised the Inheritance Tax Act. This revision covers 57 pages of text. Because of its length no attempt is made to condense or abstract this law in this publication. Details of the inheritance law may be found in Chapter 114 of the Session Laws for Colorado, 1927.

It might be well for interested farmers to study this law carefully. The exemptions granted and rate of taxation under the present law are as follows:

Class A usband, wife, rent, adopted hild, or lineal issue	Class B Wife, widow of son, or husband of daughter, grandparent, brother or sister	Class C Uncle or aunt, nephew or niece, or lineal descendant	Class D All others	
Widow $20,000 Others $10,000	$2,000	$500	$500	**Exemption**
% on first 0,000 up to ½% over $150,000	3% on first $10,000 up to 10% over $200,000	4% on first $2,500 up to 14% on excess over $500,000	7% on first $2,500 up to 16% on excess over $500,000	**Rate**

FARM TAX CALENDAR

January

Assessor must furnish tax schedule (7225). **Jan.1**

Taxpayer may appeal from assessor's decision to unty commissioners (7287). **Before first Monday**

Last year's taxes are due January 1. Last day for sessor to deliver tax list and warrants to county treaser (7317). **Jan. 1**

February

Fill out tax schedule.

Taxes may be paid in two equal payments. To avoid nalties, the first half must be paid prior to March 1, and e second half must be paid prior to August 1. (Amend. 7191, Ses. Laws, 1925 and 1927) **Feb. 28**

March

From March 1 to August 1 the first half bears inter- at the rate of 10 percent per annum for each month fraction thereof. (Amend. to 7191, Ses. Laws, 1925 d 1927) **March 1**

April

April 1 Return tax schedules to assessor whether prope
is owned or not. (7225, 5251)

April 1 Assessment day, real and personal property. (72
7249)

April 1 Lien of general taxes for current year attached
all property. (7180)

First Monday State Board of Equalization meets to assess pub
utilities. (7284)

April 30 If entire tax due for the year is paid before May
no penalty will be attached. (Amend. to 7191, Ses. Lav
1927)

May

May 20 Last day for returning tax schedules to assess
(7225)

June

June 15 State Board of Equalization must certify the amou
and value of public utility property assessed in each cou
ty to assessors and county clerks. (7284)

June 15 Tax commission transmits details of public util
assessments to county clerk. (7308)

June 15 Apportionment of public utility property amo
school districts and municipalities by county commissio
ers. (7309)

July

July 31 Final payment of taxes is due. (Amend. to 7191, S
Laws, 1927)

August

First Tuesday Assessor must mail notice of change in valuati
other than that given in taxpayer's schedule. (7291)

First Tuesday Assessor must give notice of hearings to objectio
to the assessment. (7291)

Aug. 1 Whole amount of tax becomes delinquent and bea
interest at rate of 10 percent per annum until the pr
erty is sold. (Amend. to 7191, Ses. Laws, 1927)

Aug. 1 Treasurer mails notice of tax delinquency. (7402)

Aug. 20 Treasurer mails notice describing land to be s
for taxes. (7402)

Last day in which to file petition on tax complaint th State Tax Commission. (7287) — **Aug. 25**

Taxpayers may appeal from assessor's decision to unty commissioners until first Monday in January.

September

Assessor must transmit abstract of property in his unty to State Tax Commission. (7351, 7268, 7311) — **First Monday**

State Tax Commission meets to hear complaints. 287) — **Second Monday**

Meeting of county commissioners as County Board Equalization. (7458) — **First and third Tuesday**

October

Last day for State Tax Commission to change as-ssed valuations of counties. (7352) — **Oct. 1**

State Tax Commission must give decision on all tax nplaints or petitions. (7287) — **Oct. 1**

County assessor shall certify before this date total luation of assessable property within each city, town school district. (7224) — **Oct. 25**

Meeting of Board of Equalization to make state levy l complete equalization of county assessments. — **Third Monday**

State Board of Equalization meets to correct errors, l adjust and equalize assessments in the several coun-s of the state. (7463) — **First Monday**

November

Property will be advertised for sale for delinquent es. (Chap. 148, Ses. Laws, 1925) — **Nov. 1**

School boards, cities and towns shall make their levy l certify same to county superintendent of schools. 224) — **Nov. 1**

County commissioners levy the required tax for the ar. (7457) — **First Monday**

Application for motor vehicle license can be made. hap. 149, Ses. Laws, 1923) — **Nov. 15**

December

Sale of property for delinquent tax will begin on or out December 1. (Chap. 148, Ses. Laws, 1925) — **Dec. 1**

Motor vehicle license expires. — **Dec. 31**

Bulletin 356 November, 1929

IMPROVEMENT OF SAGEBRUSH RANGE IN COLORADO

Herbert C. Hanson

Colorado Agricultural College
Colorado Experiment Station
Fort Collins

The Colorado Agricultural College

FORT COLLINS, COLORADO

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*On leave, 1929

IMPROVEMENT OF SAGEBRUSH RANGE IN COLORADO

PROGRESS REPORT OF 1927-1929 EXPERIMENTS

BY HERBERT C. HANSON

Sagebrush in Colorado marks the eastward extension of the large sagebrush formation in Utah and Nevada[1]. It occupies a large portion of Colorado. Since so much of Colorado is occupied by sagebrush, most of which is of low grazing value, experiments were started in 1927 on the improvement of this type of range for grazing. The object of this report is to make available information that has been gathered during the past three seasons.

Sagebrush is best developed in the western tier of counties and in mountain parks, particularly in North Park and the Laramie River Valley in Northern Colorado. A vigorous stand is also found in the southeastern part of the San Luis Valley. Occasional patches occur as far east as the vicinity of Estes Park and Virginia Dale.

A number of other shrubs may be associated with sagebrush. The most common ones are species of rabbitbrush and saltbush. Oak brush, pinyon, aspens or lodgepole pines frequently alternate with the sage. The annual mean precipitation ranges from about 10 to 18 inches.

In shallow soil the sagebrush is scattered and low, often a foot or less, but in deep soil it may reach a height of 6 feet and form dense stands. As a rule when sagebrush is dense and is 3 or more feet tall it indicates a deep soil that contains no or very little alkali. (Fig. 1). Areas covered with such a stand are usually considered excellent for growing crops of potatoes, alfalfa and small grain.

GRAZING VALUE OF THE SAGEBRUSH TYPE

White sagebrush *(Artemisia cana)* is considered a good browse plant during fall and winter for sheep and cattle. It is not so abundant, however, as black sagebrush *(Artemisia tridentata)* which is much less palatable to both sheep and cattle. It furnishes consider-

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(1) Robbins, W. W. 1917. Native vegetation and climate of Colorado in their relation to agriculture. Colo. Agric. Exp. Sta. Bul. 224.

Fig. 1.—Sagebrush in the Laramie River Valley before burning. This area was selected for the experimental work. October 4, 1927.

able feed for sheep during the winter when other plants are covered with snow.

On areas covered with short sagebrush there may be many shallow-rooted grasses such as grama grass, June grass, sedges, fescue, muhlenbergia, arid bluegrass, wheat grass and a variety of weeds as cinquefoil and cat's paws. The growth of these plants is usually too short, however, to furnish much feed. Such range can best be utilized by sheep. When the sagebrush is removed by scraping or grubbing, the growth of grasses becomes denser and taller.

On areas covered with dense sage, 3 or more feet tall, a large variety of deep-rooted grasses is found. Due to the competition of the sagebrush these grasses are usually very sparse. They form only small clumps or only single stalks (Fig. 7). Most of them are excellent forage plants. Common species are wheat grasses, blue grasses, porcupine grasses, sedges and fescues. Usually, however, they are too scattered or are too inaccessible in the brush to be grazed much.

EXPERIMENTAL METHODS

The experimental work is being conducted at an elevation of about 8000 feet in the Laramie River Valley in Northern Colorado. The sagebrush area that was selected is on a gentle east slope. The

soil is a deep sandy loam. Roots of the black sage there have been found down to a depth of 10 feet.

The vegetation was almost a pure stand of black sage averaging about 3 feet tall (Fig. 1). Grasses, lupines, other weeds and rabbit-brush were scattered thinly between and under the sagebrush plants. Previous experiments in this locality to increase the stand of grass by broadcasting seeds of slender and crested wheat grasses were total failures. Not a seedling was found.

An area 150 feet long by 100 feet wide was selected. On half

Fig. 2.—Burning and grubbing almost completed. The strip in the foreground was grubbed, that in the background burned. October 5, 1927.

of it the sagebrush was grubbed out, on the other half the sagebrush was burned. The burning was done on October 5, 1927, with a moderately strong west wind (Fig. 2). The plot was then divided into three strips, each 50 by 100 feet. Half of each of these strips had been grubbed, the other half burned. One of these strips was seeded in the fall of 1927 (October 5), another strip seeded in the spring (May 20, 1928) and the third strip was not seeded. The spring seed mixture consisted of smooth brome grass, slender wheat grass, crested wheat grass, orchard grass and yellow sweet clover. Only brome grass was seeded in the fall. The seed was broadcast and then raked in to imitate harrowing.

After the spring seeding was completed on May 20, 1928, a

Fig. 3.—Rodent exclosure, 50 by 100 feet, erected after the spring seeding was finished. May 21, 1928.

Fig. 4. The experimental area as it appeared on July 26, 1929. Figures 2, 3 and 4 were taken from the same corner of the area.

rodent exclosure 100 feet long and 50 feet wide was built (Fig. 3). Three-foot chicken wire netting, one-inch mesh, was used. A shallow trench was dug so that the lower part of the fence could be turned outward and then covered with a few inches of soil. Poisoned grain was scattered inside to kill rodents within the fence. A barbed-wire fence to exclude cattle and horses was placed around the entire plot a few days later (Fig. 4).

To summarize, the experimental area furnished the following conditions:—

I. PROTECTED FROM GRAZING BY LIVESTOCK

1. Burned sagebrush, seeded October 5, 1927, exposed to rodents.
2. Burned sagebrush, seeded October 5, 1927, protected from rodents.
3. Burned sagebrush, seeded May 20, 1928, exposed to rodents.
4. Burned sagebrush, seeded May 20, 1928, protected from rodents.
5. Burned sagebrush, not seeded, exposed to rodents.
6. Burned sagebrush, not seeded, protected from rodents.
7. Grubbed sagebrush, seeded October 5, 1927, exposed to rodents
8. Grubbed sagebrush, seeded October 5, 1927, protected from rodents.
9. Grubbed sagebrush, seeded May 20, 1928, exposed to rodents.
10. Grubbed sagebrush, seeded May 20, 1928, protected from rodents.
11. Grubbed sagebrush, not seeded, exposed to rodents.
12. Grubbed sagebrush, not seeded, protected from rodents.

II. NOT PROTECTED FROM GRAZING BY LIVESTOCK.

13. Burned sagebrush, not seeded, exposed to rodents.

In order to determine in detail the changes in the vegetation, 16 meter-square quadrats were established. On all of these the abundance of each species was determined and photographs taken each year. On some the vegetation was clipped at 1 inch in order to determine the amount of dry matter produced.

The quadrats were located as carefully as possible in order to get typical areas. Some of the quadrats were located before the sagebrush was burned. It was difficult to find large enough areas between the clumps of sagebrush for a square-meter quadrat.

The quadrat areas had more plants on them than those in the clumps so the error would be in representing too much vegetation for unburned sagebrush rather than too little. It should be emphasized, however, that extreme care was used in locating each quadrat.

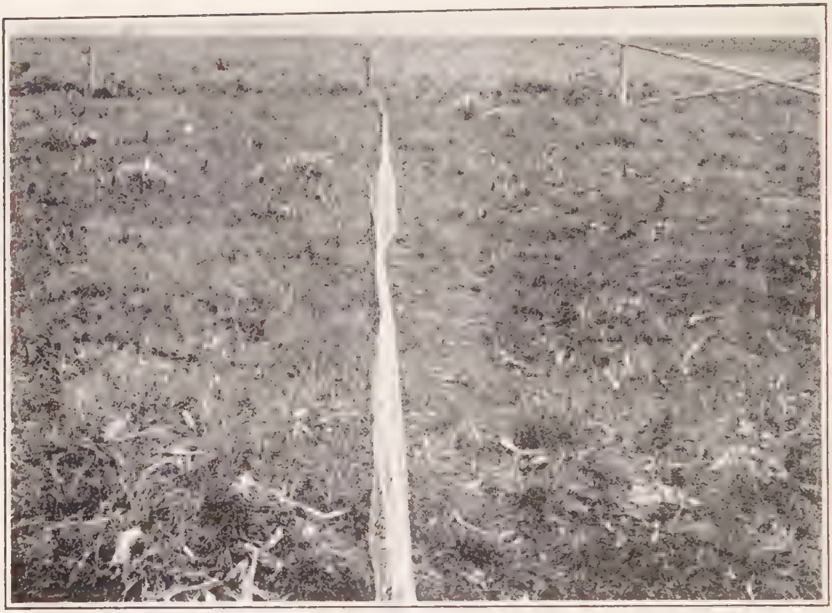

Fig. 5.—Natural revegetation and the effect of rodents the first season following destruction of the sage. Area on left of fence protected from rodents for one season, area on right not protected from rodents. August 17, 1928.

Fig. 6. The same view as shown in Figure 5 but about a year later. Grasses, especially western porcupine grass, are more abundant and lupine is less vigorous and less abundant. July 26, 1929.

RESULTS OF THE EXPERIMENT

1. There was a good stand of highly palatable and nutritious grasses and lupine in the summer following the burning and grubbing (Fig. 5). The chief grasses were western wheat grass, western porcupine grass, blue grasses, trisetum and Letterman's needle grass.

2. Seedlings and left-over stalks of sagebrush were very few on both the grubbed and burned strips. No left-over stalks were found on the burned strip and seedlings appeared to be fewer than on the grubbed strip.

3. The stand of grasses was much better within the rodent exclosure than elsewhere (Fig. 5) and it was better on the part protected from grazing by cattle and horses than on the part grazed.

4. Reseeding did not materially increase the stand. Plants of the tame grasses appeared only in much-disturbed soil as along the chicken-wire fence where the soil had been turned up, and around rodent holes where there was some loose, bare soil.

5. The stand of grasses increased materially under all conditions during the second season (1929). Lupines decreased in vigor and in number. They bloomed profusely in 1928 but in 1929 there were few flowers (Figs. 5 and 6). The sagebrush plants grew only a little and a few new ones appeared.

6. The seeded tame plants grew slowly but the stand of these did not increase during the second season. The most successful were

Fig. 7.—Meter-square quadrat number 3A before the sagebrush was burned. This plot is typical of rather large openings between the sage clumps. July 23, 1927.

brome grass, slender and crested wheat grasses. These three produced some seed in 1929. Yellow sweet clover grew only 1 to 2 inches tall.

7. The yields secured from the clipped quadrats, one-meter square, established and clipped first before the area was burned, are given in table form. All of these were protected from grazing by cattle and horses.

Oven-dry Weights of Plants Clipped at 1 Inch

LOCATION		1927, before eradication, grams	After eradication 1928 Grams	1928 Percent increase	1929 Grams	1929 Percent increase[1]
1A, burned,	grass		37.0		46.4	
fall seeded,	weeds		21.0		14.4	
exposed to rodents	total	18.0	58.0	222	60.8	238
2A, burned,	grass		43.5		86.2	
not seeded,	weeds		9.0		3.6	
protected from rodents	total	20.6	52.5	155	89.8	336
3A, burned,	grass		27.9		79.0	
spring seeded,	weeds		0.3		2.0	
exposed to rodents	total	20.1	28.2	40	81.0	303
4A, grubbed,	grass				96.3	
spring seeded,	weeds				12.7	
exposed to rodents	total	16.9			109.0	545

([1] Percentage increase over 1927 yield)

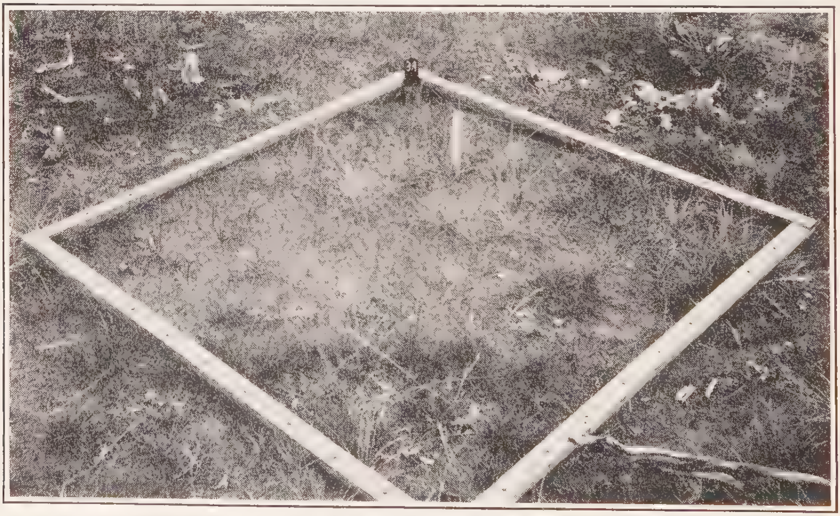

Fig. 8.—The same plot as shown in Figure 7 but in the first season following burning. Note the burned-off sage stumps at the left, the remains of the sage clump shown at the left in Figure 7. August 17, 1928.

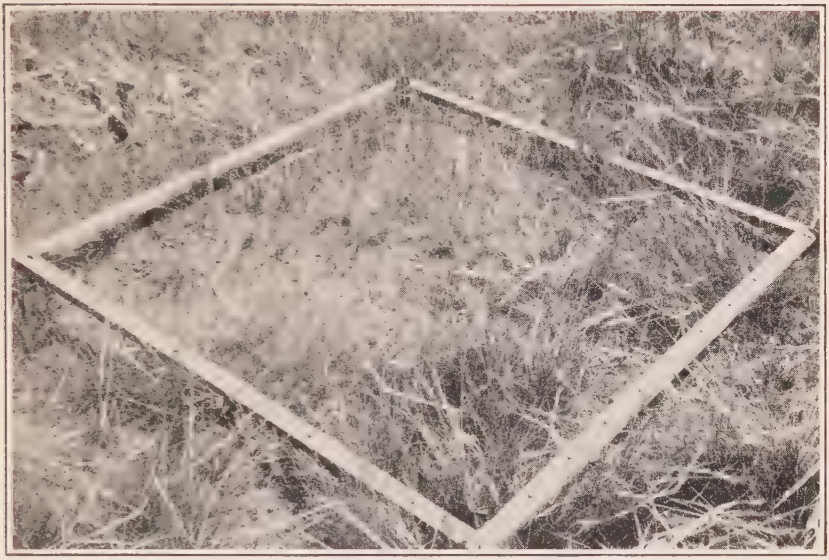

Figure 9.—Quadrat 3A in the second season following burning. This is the same plot as shown in Figures 7 and 8. The sage stumps are still in evidence at the left. All of this grass is highly palatable and nutritious. July 25, 1929.

The increase in the yield of vegetation the first year after burning varied from 40 to 222 percent over the yield in the native sagebrush the year before. The increase in the yield in the second year over the yield in the native sagebrush 2 years before varied from 238 to 336 percent. It is probably worth stating again that these quadrats were located before the area was burned. The yield of grass was much greater than the yield of weeds and the grasses increased greatly the second year while the weeds decreased. The variations in the weights of material from the different quadrats are probably due more to local variations in intensity of burning, soil conditions, etc., than to conditions of the experiment.

SUMMARY

1. Experiments are being conducted on the improvement of sagebrush range in the Laramie River Valley in Northern Colorado.

2. The stand of highly palatable and nutritious grasses was greatly increased the first year following removal of the sagebrush by burning and grubbing. The stand increased even more the second year. Increases in the weights of the forage from clipped plots the second year after burning were 238 to 336 percent above the weights before burning.

3. Burning was more successful than grubbing in destroying the sagebrush.

4. Dense stands of sagebrush 3 or more feet tall can be readily burned with a suitable wind. The burning in this experiment was done in October.

5. Artificial reseeding was not necessary. Natural revegetation by the grasses on the ground was very satisfactory.

6. The experiments show that rodents greatly decreased the amount of forage.

7. Burned areas should be only lightly grazed before the seeds have matured the first two seasons after burning so as to give the grasses opportunity to grow. Cattle, horses and rabbits concentrate their grazing on burned areas.

8. It appears that the grasses can hold the sagebrush in check for a considerable time. Observations made on areas that were burned 5 to 10 years ago indicate that the stand of grasses is still very good, even when heavily grazed by livestock and rodents.

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THE HOME VEGETABLE GARDEN

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THE HOME VEGETABLE GARDEN

By A. M. Binkley

The problem in every home is to provide sufficient quantities of healthful, palatable and wholesome food for family use. The food value of vegetables in a diversified diet is now quite generally recognized as of fundamental importance to health. This recognition is measured by the increase in consumption of vegetables during the past few years and a still further increase is noted in the number of inquiries received by the Department of Horticulture for information on vegetable gardening. In view of these facts this publication is deemed advisable to furnish the inexperienced gardener with such information as will be of material benefit to him in the growing of vegetables for family use.

The soils and climate of Colorado are especially favorable to the production of high-quality vegetables. The growing of vegetables has developed in the state the past few years to quite an extensive commercial scale in the high-altitude sections, which is further evidence that the state is favorably adapted to the growing of vegetables of high quality and high yields per acre. The length of the growing season in the state varies considerably according to altitude and latitude, and the annual amount and distribution of rainfall varies, however there is not one section of the state which cannot grow a supply of some of the more common fresh vegetables for family use.

Every family should have a vegetable garden for the following reasons: (1) It will reduce the family food bill. (2) It provides an abundant supply of fresh, high-quality vegetables in season. (3) It will supply the family with vegetables for canning, drying and for winter storage. (4) It will permit a substitution of vegetables in some cases for the more expensive foods. (5) It provides a more healthful diet. (6) It will permit the opportunity to grow prize vegetables for the community fairs.

The most important reason for maintaining a vegetable garden is that of economy, a point that cannot be over-emphasized, and should be measured in net returns in yields above costs of labor and materials. The city gardener often finds the vegetable garden a place for pleasant exercise in the form of outdoor recreation. On the other hand, the garden on the farm is considered necessary and should be arranged so that it can be taken care of for the most part by horse-drawn implements.

Location of the Garden

In selecting the site for the garden, care should be taken in the matter of location, and the following points considered:

(1) It should be near the house for convenience and because it is oftentimes a spare-hour proposition.

A mountain vegetable garden grown at an elevation of 7000 feet above sea level.

(2) A south slope is desirable as the soil usually warms up earlier in the spring and permits earlier planting.

(3) It should have good drainage, both for water and air.

(4) Vegetables require plenty of sunshine and the vicinity of large shade trees should be avoided.

The city lot gardener usually has little choice in the matter of location, and must use whatever space is available, while the farm gardener has more selection.

A good fence around the garden is an important item to protect the crops from livestock and more especially poultry.

Garden Soils and Preparation for Planting

With the proper understanding of soils, almost any soil can be fitted into a good garden type by supplying organic matter and plant food in the proper amounts. It is often impossible to select the soil type, but this should not prevent one from having a good garden. A sandy-loam type with plenty of plant food is desirable. This type warms up earlier in the spring and permits the planting and growing of earlier crops. It drains readily, can be worked shortly after a rain, and does not bake or crust.

Plowing or spading the garden plot in the fall is preferable as it will permit earlier spring preparation and planting. Manure turned under in the fall will decompose more rapidly and be more available for early crops than if turned under in the spring. It is

better to leave the soil rough, as plowed or spaded, to hold the winter snows and permit the storage of soil moisture. The alternate thawing and freezing winter weather produces an action which breaks up the clods and mellows the surface soil. Insects are exposed to the weather and are usually destroyed. The soil should be broken to a depth of 10 to 12 inches, which will be sufficient for the development of root crops. Spring plowing can be done, provided conditions are such that fall preparation could not be taken care of. Soil worked in the spring oftentimes leaves openings that dry out rapidly.

After plowing or spading the garden, the soil should be pulverized thoroly and worked down to a smooth, fine, firm condition. In case of the small garden this can be accomplished by raking, while on the larger farm gardens, the soil should be disced in the spring, when fall plowed, and then harrowed alternately and leveled with a drag for the smoothing touches. If seeds are planted in coarse, lumpy soil they will be covered at different depths, and the result will be a poor stand and a poor yield. A careful final preparation of the seedbed is essentially important and cannot be over-emphasized.

Fertilizers

There is a wide variation in soil types, usually determined by the stage of decomposition and the relationship to the parent material. It is generally known that Colorado soils are lacking in humus or organic matter and rich in mineral matter, so the need for manure is readily understood. Well-decomposed manure applied in the fall of the year, disced in and plowed under, gives much better results than spring manuring. Stable manure is undoubtedly the most desirable for the garden, as it supplies the much-needed humus, as well as additional plant food. An application of 20 tons of such manure per acre will produce satisfactory results on most soil types. Manuring will loosen up the soil, enable the soil to take in more water to be stored in the subsoil, render it more drouth resistant during the hotter part of the summer, and will, as a rule, make it work easier. Cow manure is heavier than horse manure and can be used on the lighter soil types. Poultry manure is one of the richest and most concentrated of farm manures and should be used sparingly as a heavy application is likely to burn the more tender crops.

Green-manure crops such as sweet clover or rye, if plowed under in the fall, promote quicker rotting. Not only does the soil become richer and produce better yields, but there is a noticeable difference in the easier handling of most soils. The legumes such as the clovers, cowpeas, and soybeans add considerable nitrogen to the soil. Green-manure crops readily fit into the garden plan, and as soon as the early crops, such as radishes, are harvested, the area can

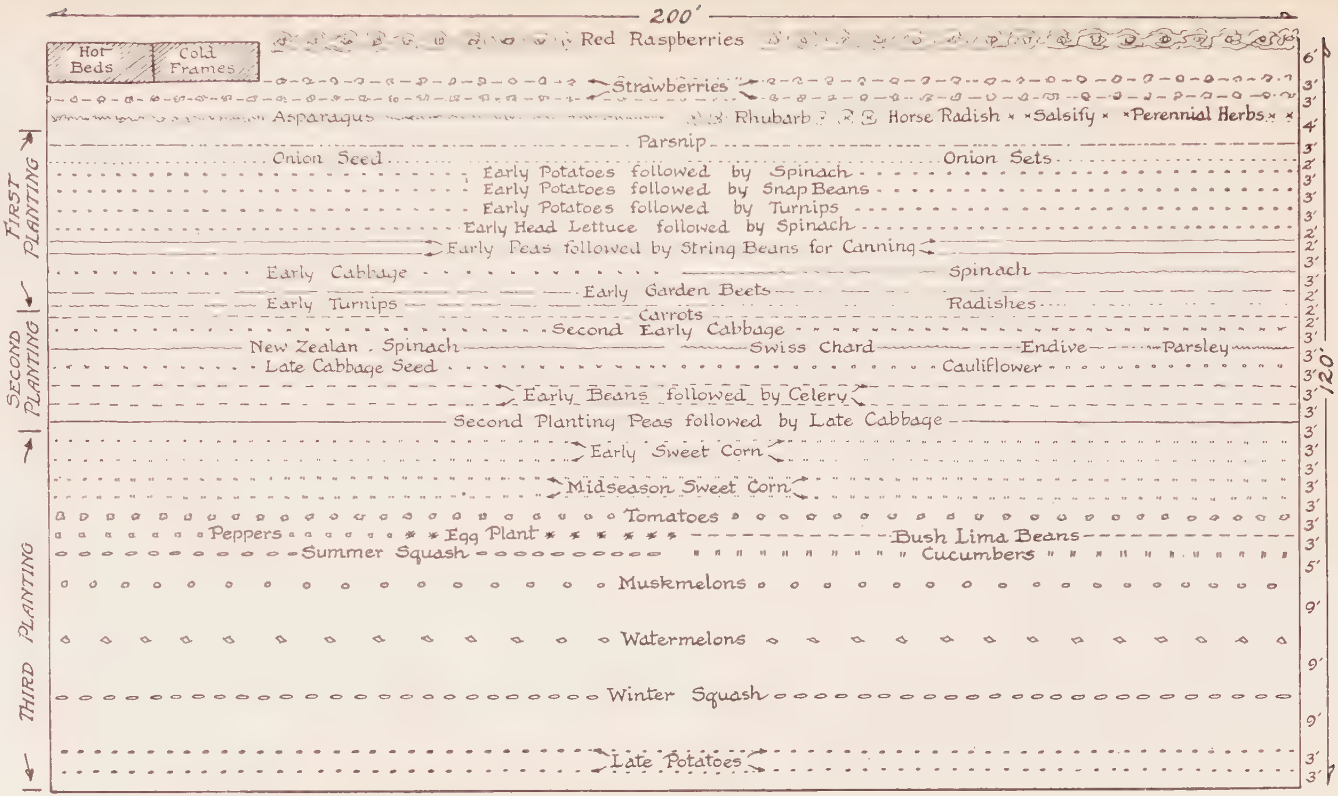
be planted to a rapid-growing green-manure crop and turned under in the fall. Space in the garden that becomes idle in July can be profitably planted to green-manure crops and turned under in the fall. Rye can be planted from the middle of August to the first of September and where area is not needed for early spring vegetables, can be turned under in the spring.

Commercial fertilizer can be used to advantage where manure is not available. However, in no case should commercial fertilizers be used continuously without adding humus to the soil in the form of green manure or barnyard manure. From results of a preliminary nature it has been found that a complete fertilizer (one containing all of the three important plant food elements), such as a 3-12-4 combination, will produce good increases in yields on the lighter soil types. The growth response is also good when a straight phosphoric acid fertilizer is applied on the heavy-type soils. The commercial fertilizer should be applied at the rate of 200 to 400 pounds per acre. It will burn the germinating sprout if the seed is planted directly with it; this is especially true of the more tender crops. It may be applied by broadcasting over the seedbed before planting and harrowing or raking it in, or it may be sown in a shallow furrow from 2 to 4 inches from the plants and the furrow covered.

Planning the Garden

The plans for the family garden should be made on paper early in the year to show the arrangement of crops. The rows should be laid out to give long rows for planting, then the number of rows, location of the crops, planting distances, and vegetables to be grown should be put down on the plan. The vegetables should be arranged according to the number of days required for maturing. The early maturing groups such as lettuce, and radishes should be planted together and such space can be used for a second planting. The late-maturing crops, such as cabbage and cauliflower, also are planted in the same area, which will permit the growing of companion crops in between the rows, such as green onions or radishes.

Perennials, such as asparagus, rhubarb, small fruits and herbs, should be planted on an outer side of the garden where they will not be disturbed by cultural operations required by the other crops. In doing this, if the garden is plowed with a team of horses, such crops will not be run over or injured.



Plan for a farm garden.

The growing of companion crops, for example the growing of early bush beans between rows of tomatoes, is an economical practice. Squashes and pumpkins can be grown along with sweet corn, and early maturing cabbage may be set in between wide rows of corn or tomatoes. The gardener, after some experience, can determine what crops to grow as companion crops and can then get the most out of a limited space. Where gardens are cared for by horse-drawn implements, companion crops of course are not practical. However, to obtain the best results from a small garden, the soil should be kept producing as long as the season permits. Lettuce and radish crops may be grown one crop following another. The root crops, when planted early, often become hard and woody and lose quality by the time they are ready for winter storage. For winter storage of root crops it is better to make a second planting about the first week in July. This practice will produce roots that carry quality for winter storage.

Garden Seed

In buying seed, demand high quality and be ready to pay for the extra value, because in the long run such seed will be found to be the cheapest. The yield and quality secured at harvest time will more than pay the extra cost. After the amount and kind of seed is definitely determined for the garden according to the plan, it can then be ordered early, much in advance of the planting season. By using a definite plan to order from, the exact amount of seed can be secured, and the waste from surplus thus reduced to a minimum. Reliable local dealers who observe the performances of seed sold to gardeners, can supply seed that will meet the growers' requirements. Where the garden is so situated that purchases cannot be made direct from seed dealers, such seed can be ordered from a reliable seed company, thru mail order. In ordering from the seed catalogs, it is generally better to select the standard varieties rather than the highly featured new varieties.

In case old seed is left over it is especially important that a germination test be made. This can be accomplished by counting out 50 to 100 seeds and placing them between moist blotting paper in a shallow dish and covering them with another dish. After 4 or 5 days at ordinary room temperature the viable seeds will sprout if the paper is kept moist and the percentage germination can thus be determined. A sample of seed can also be sent to the Colorado Seed Laboratory at Fort Collins, where a purity count and germination test will be run free of charge.

In growing seed for your own use it is desirable to select plants for seed production that are especially vigorous and high yielders.

This can be accomplished with very little additional work with the common annuals, especially where the fruit is the edible part. Any of the root crops or biennials which must be stored thru the winter and set out the second year for seed production do not prove to be economical crops to secure seed from for the home garden. Seeds should be stored in a cool, dry room, preferably in sealed jars, so that their germination will not be readily lost. High air humidity is especially destructive to the germination of seeds. In many instances new growers have difficulty in estimating the amount of seed required to plant the garden, and accordingly the accompanying table has been prepared. The amount of seed required, depth of planting, time of planting and distance to plant are tabulated for information to beginners.

Planting Table

There is considerable range in the climatic conditions of the state and the length of growing season varies, so that in consideration of these factors, only the approximate dates for planting are given in the above table. Where it is necessary to plant seeds in a hotbed in order to grow plants, it is noted in the time-of-planting column.

VEGETABLE PLANTING TABLE

Vegetables	Per 100-Ft. Row		One Acre	Rows Apart		Plants Apart In Row, Inches	Depth of Planting, Inches	Time of Planting In Open Ground	Ready for Use After Planting
	Seeds	Plant		Horse Cult. Inches	Hand Cult. Inches				
Asparagus		50		36–60	24	10–18	10–12	Early Spring	2 years
Dwarf Beans	1 pt.	300–600	40 lbs.	20–36	15–18	2–4	1	May and June	50-75 days
Pole Beans	½ pt.	30–50	30 lbs.	48	48	40	1	June	75-80 days
Lima Beans	½ pt.		40 lbs.	36	24	6–10	1	June	60-75 days
Beets	1½ oz.	600	10 lbs.	20–24	12–18	2	¾	April August	45-50 days
Broccoli	¼ oz.	65	4 oz.	30–36	20–24	18–24	½	April and May	100-130 days
Brussels Sprouts	¼ oz.	70–100	2½ oz.	30–36	24–30	16–24	½	May and June	100-120 days
Early Cabbage	¼ oz.	60–100	¼ lb.	30–36	24–30	12–18	½	Apr. Start in hotbed in March	130-140 days
Carrot	½ oz.	600	2 lbs.	30–36	18–24	2	¼	April, May, June	55-80 days
Cauliflower	¼ oz.	80–100	1 oz.	30–36	24–30	14–18	½	April to June	175 days
Early Celery	¼ oz.	300	¼ lb.	24–36	18–24	4	⅛	May and June. Start in hotbed in early March	120-150 days
Late Celery	¼ oz.	300	¼ lb.	36–72	18–36	4	⅛	June and July. Start in hotbed in May	120-150 days
Witloof Chicory	½ oz.			24–30	18–20	4–6	½	June	125 days
Sweet Corn	½ pt.		6 qt.	36–40	30–36	4 every 3 feet	1–2	May–July	60-90 days
Cucumber	½ oz.		2 lbs.	48–72	48–72	4 every 3 feet	1	April and May	50-100 days
Egg Plant	⅛ oz.	70	¼ lb.	30–36	24–30	18	½	April and May. Start in hotbed during March	125-140 days
Kohl Rabi	½ oz.			24–30	18–24	6	½	April and May	65-75 days
Lettuce	½ oz.	120	2½ lb.	24–30	12–18	10–12	¼	March–July	70-90 days

Vegetables	Per 100-Ft. Row		One Acre	Rows Apart		Plants Apart In Row, Inches	Depth of Planting, Inches	Time of Planting In Open Ground	Ready for Use After Planting
	Seeds	Plant		Horse Cult. Inches	Hand Cult. Inches				
Muskmelon	½ oz.		2 lb.	60–84	60–84	4 every 4 feet	1	April–June	85-150 days
Watermelon	½ oz.		2 lb.	84–144	84–144	4 every 6 feet	1	May and June	100-130 days
Onion Sets	2 qts.	600		20–36	12–18	6–12	1	March–May	130 days
Onion Seed	1 oz.	600	2½ lb.	20–24	18	2–4	½–1	March and April	100-180 days
Onion Seed for Sets	1 lb.	2400	50-60 lbs.	20–36	12–18	Crowded	½	March	95 days
Onion Plants—Transplanting	½ oz.	350	8 oz.	20–36	14–18	3½–4	¾	April–May	130-140 days
Parsnip	½ oz.	300	3½ lb.	20–36	18–24	4	½	April and May	140 days
Peas	1 pt.	1200	40-50 lbs.	36	30–36	1	1	March–May	65-80 days
Pepper	⅛ oz.	80	2 oz.	20–36	18–24	15	½	May and June. Start in hotbed in March	130-150 days
Irish Potatoes-Dryland	5 lbs.	60	10 bu.	42	42	17–20	5–6	April–June	130 days
Irish Potatoes-Irrigated	12 lbs.	100	20-25 bu.	32–36	24–30	12	4	March–June	90–150 days
Pumpkin	½ oz.	64	3½ lbs.	84–96	84–96	4 every 6 feet	1	May and June	75-110 days
Radish	1 oz.	1200	8 lbs.	20–36	12–20	1	½	March–September	25-75 days
Rhubarb roots	30 roots	30		36–60	36–60	42	3–4	April	2 years
Spinach	1 oz.	400	10 lbs.	20–36	12–20	3	½	April–July	50-70 days
Summer Squash	½ oz.	80	3½ lb.	36–48	36–48	4 every 4 feet	1	May–June	65- 70 days
Winter Squash	½ oz.	64	2 lb.	84–108	84–108	4 every 6 feet	1	May and June	120 days
Tomato	⅛ oz.	33	2 oz.	36–48	36–48	36x36	½	May and June. Start in hotbeds	100-150 days
Turnip	½ oz.	600	1 lb.	20–36	18–24	2	½	April and August	45-90 days

Setting Plants in the Field

Hotbed plants are often transplanted once before they are set out in the field, and it is a distinct advantage to do so as it gives plants a chance to develop better root systems. It produces better plants, secures earlier crops and provides more space. In many cases, gardeners feel that transplanting from the hotbed to the field is all that they can afford, and select only the strong vigorous plants in the seedbed for setting out in the field. It is difficult to transplant sweet corn, cucumbers, melons and beans. These crops may be transplanted by sowing the seed in paper pots or small baskets and after the plants are 4 weeks old they may be set out without disturbing the root system. Cabbage, cauliflower, broccoli, head lettuce, onions, tomatoes, celery, peppers and eggplant are easy to transplant. However, the following precautions should be observed, to reduce losses:

1. The soil should be well watered before disturbing the plants in the seedbed.
2. Do not allow the plants to become dry after removal from the bed until they are set out.
3. Do not pull plants from the seedbed without loosening the soil. Leave as many roots as possible on the plants.
4. Water the soil before and after setting the plant.
5. Press the soil firmly about the roots after setting.
6. Shading the plants a few days after transplanting can be done on a small scale.

Hotbeds and Coldframes

Detailed information concerning the making and handling of hotbeds and coldframes may be secured in Bulletin 328, Horticultural Department, Colorado Experiment Station, Fort Collins, Colorado. This publication will be sent to all those who request it, free of charge. It is important that the gardens have some sort of structure to start plants in and to grow them for transplanting. They can also be used for growing early crops of cucumbers, radishes or lettuce. Any information desired on handling plants in the hotbeds, transplanting to the field, hotbed diseases and management in general, can be found in this publication.

Sowing the Seed

It is very necessary in planting garden seeds that the soil be in a very finely pulverized condition that can be readily worked. In order to secure the best stand the soil must have the proper moisture and the soil particles must be compact, free from clods, and not too dry to insure a good germination. In many instances it is a good plan in dry springs to irrigate the garden ground before planting.

As far as the small garden is concerned it is often of advantage to sow the seed by hand rather than with a seed drill. Smaller seeds should be planted considerably thicker than the large seed to insure a good stand. The depth of planting varies also with the nature of the soil, the kind of seed used, and whether or not the season is dry or wet. The planting table will be of value in determining the proper depth to plant the seeds. In making rows in the garden it is often advisable to stretch a string along the row so that the rows can be made straight and the seed sown without moving the line. This can be accomplished by the use of an ordinary garden hoe. In a good many instances where the spring is especially dry it would be an advantage to irrigate the crops after planting. This can be accomplished by making a furrow along side of the row and the water run down it. It is also a good practice to slightly tamp the soil above the seed so that there is much better capillary action in the soil moisture and a quicker germination brought about.

Paper mulch experiment.

Mulching

During the past few years there has been considerable publicity given to the use of paper mulch as a means of increasing yields. According to the work the department is doing with paper mulch, it has been found that it hastens germination, and practically eliminates cultivation and weeding. The heavy-type paper prevents the growth of weeds thru it and prevents the evaporation of moisture

from the surface of the soil. One should investigate the type of paper which he wishes to use before buying. There are several undesirable papers on the market which are not satisfactory for use. Investigations with paper on the Experiment Station plots have shown that the lighter-type papers will shrink after laying, so that they will break apart and leave wide spaces uncovered.

The cost of the paper used in the paper-mulch experiments varies widely with the type used. However, a fairly good type of paper can be purchased at around $2.50 for 5400 square feet. So far the use of paper mulch under Colorado conditions is still in the experimental stage and there are many problems connected with its use which must be worked out before it can be recommended for general use.

One of the factors which gives considerable trouble is the laying of the paper over irrigation furrows. During the growing season the rainfall is often not sufficient to properly mature the crop, even under paper mulch, without the use of supplementary irrigation water. It would be advisable for growers who wish to use such paper to try it out on a small scale in their home gardens before using it on any large scale. As a general thing it has been found that warm-season crops such as sweet corn, cucumbers and tomatoes, have given considerably increased yields under paper mulch, and the cool-season crops, such as head lettuce and potatoes have not shown very large increase in yields over the unmulched plots. For the small home garden, paper mulch can be used to an advantage where only a very small amount of time is available for work in the garden. It will tend to keep weeds down while one is away for a week or two and it will save the necessity of weeding and cultivating. As a rule one weeding is all that is required during the growing season. This can be accomplished at the same time the row vegetables are thinned.

Thinning

In planting vegetables having small seed, generally the seed is too thick and the plants will grow in a very crowded condition. This is especially true of the root crops and thinning should be started just as soon as the third or fourth pair of true leaves have developed. Thinning at this stage will prevent the growth of weak spindly plants. In thinning, the plants should be left at the proper spacing, usually 2 to 6 inches apart in the row and the largest plant in each bunch left in the soil. By leaving the large and most vigorous plant in each bunch, a larger and earlier yield may be secured.

Irrigation

In Colorado there must be a good supply of water available to profitably grow vegetable crops, as there are but few localities in

the state that can grow such crops without supplementing rainfall with irrigation during the growing season. This is largely due to the irregular distribution of rainfall, most of which falls during the winter and is unevenly spread over the summer months. There is, however, a wide range in the amounts of distribution of rainfall over different sections of the state, and no definite rule can be followed in the application of irrigation water. The soil type, character of the sub-soil, slope of land, the crop being grown, all determine the amount and frequency of irrigation. Irrigation should be heavy and often enough to keep the plants growing uninterruptedly during the growing season. Plants should not be allowed to become wilted or checked.

In this state there are three methods of applying irrigation water: Surface, sub-surface and semi-sub-irrigation. Surface irrigation is by far the most satisfactory method to use, especially where the furrow method of applying the water is used. This method is accomplished by running water in furrows along by the side of and close to the plants. The water should be applied when needed and the soil thoroly soaked, rather than frequent light irrigations. Excessive irrigation, however, is detrimental and should be avoided. The soil should be cultivated as soon as it is sufficiently dry after each irrigation. Irrigation may be done at any time during the day; however, early morning irrigation is preferred by many.

In using the lawn sprinkler, better results may be secured on most soil types by watering thoroly once a week rather than by sprinkling lightly every day. The general tendency in sprinkling is to apply too little water, and more economical use of water can be secured by running the water in furrows along the rows. Flooding the surface of the soil is not recommended in applying irrigation water.

In certain parts of the state natural sub-irrigation methods are in use in the production of vegetable crops, especially in the San Luis Valley. The water table is close to the surface of the soil and by running water in a large ditch surrounding or thru the field the water table is raised so that it comes in contact with the roots of the crop. The ditch is usually filled with water and allowed to stand until sufficiently irrigated. Semi-sub-irrigation is also used to a limited extent and in this case the water table is raised as far as possible by sub-irrigation and the irrigation completed by furrow surface watering. The above methods are used generally on the lighter-type soils and there is little cost in applying water.

In the dryland sections of the state it is often possible to produce good gardens without the use of irrigation water. By shaping the farming methods to store the soil moisture, such as summer fal-

lowing, the furrow method of planting and listing, such crops as sweet corn, tomatoes, peppers, cabbage, squash, pumpkins and beans are grown. In many cases good gardens are grown by using the excess water pumped by the farm windmill.

Cultivation

Garden soils should be cultivated at frequent intervals and for the most part shallow. This operation will keep the surface soil well stirred, thereby forming mulch which will keep down moisture losses as well as destroy weed growth. The soil should be cultivated after each irrigation or rain as soon as the soil is dry enough to work. This will prevent the formation of crust and surface baking. As a general thing the gardener irrigates too often and heavily and neglects cultivation. Do not substitute irrigation for cultivation. It is better to cultivate at regular intervals and by so doing less watering will be found necessary for healthy growth of plants. Cultivation may be accomplished by the use of horse-drawn implements on large gardens, while on the small gardens, with narrow rows, a wheel or hand hoe may be used.

Insects and Diseases

There are usually quite a number of insects and diseases which attack garden crops and cause some loss. As a rule the gardener does not notice the injury until too late, and careful inspections should be made from time to time. Preventive measures are important and if disease is not known, write to the Colorado Experiment Station for Bulletin No. 323, "Common Diseases of Truck Crops."

The table on the next page has been prepared on garden insects and methods recommended for control.

Cultural Directions for Vegetable Crops

Asparagus is a crop which should be in every garden and is of special importance because of the high quality of the product. It is one of the earliest crops to produce in the spring and once it is planted and properly cared for, will produce for many years. It will do well on almost any well-drained soil, especially a well-fertilized deep loam; if earliness is desired a deep sandy loam is an advantage.

While asparagus plants can be grown from seed, it is as a rule more satisfactory to purchase plants from a reliable seedsman. This is especially true for the home gardener. In most cases it is better

Garden Insect Pests and Methods of Control

By GEORGE M. LIST, *Department of Entomology, C.A.C.*

Crop	Insect	Stage Which Does Damage	Type of Injury	Control Method Given Under Numbers At Foot Of Table
Asparagus	Asparagus beetle	Adult, larva	Feed upon new growth and mature stalks	1, 2
Beans	Mexican bean beetle	Adult, larva	Feed upon leaves & pods	3
Cabbage Cauliflower and Kohl-rabi	Cabbage aphis	All stages	Suck juice from leaves	4
	Cabbage worm	Larva	Eat foliage	1, 2
	Cabbage maggot	Larva	Tunnel in base of stem and roots	5
	Cutworms	Larva	Cut off young plants	6, 7
Cucumbers	Cucumber beetle	Adult	Eat leaves and stem	8
	Aphis	Adult	Suck juices from stem and leaves	4, 12
	Squash bug	Adult, nymph	Suck juice from stem	4, 9
Eggplant	Fleabeetle	Adult	Eat leaves of young plants	10, 11
Lettuce	Cutworms	Larva	Cut off young plants	7
	Grasshopper	Adult, nymph	Eat leaves of young plants	7
Melon	Same as cucumber			
Onion	Maggot	Larva	Burrow in the bulb	No satisfactory method
	Thrip	Adult, nymph	Suck juice from foliage	12
Potato	Colorado potato beetle	Adult, larva	Eat foliage	3, 13
	Flea beetles	Adult, larva	Adults eat foliage, larva feeds on tubers	10, 11
Peas	Aphis	Adult, nymph	Suck juice from plant	4, 12
Squash	Same as cucumber			
Tomatoes	Horned tobacco worm	Larva	Eat leaves and fruit	1, 2, 9
Tomato	Tomato psyllid	Adult, nymph	Suck juice from plant	12, 14
	Cutworms	Larva	Cut off plants	6, 7
Corn	Corn earworm	Larva	Eat into corn ear	No satisfactory method
	Corn-root worm	Larva	Tunnel into base of stalks and roots	15

Methods of Control

1. Dust mature plants with a mixture of air-slaked lime (5 parts) and lead arsenate (1 part).
2. Spray with a solution made of 2 ounces of lead arsenate, 2 ounces of laundry soap and 3 gallons of water.
3. Spray with magnesium arsenate or zinc arsenite (1 ounce) and water (3 gallons).
4. Dust with a mixture containing 5 percent nicotine sulphate.
5. Protect plant with tarred paper disc placed at base of plant at time of transplanting.
6. Wrap stem of plant, from roots to first leaves, with paper at time of transplanting.

7. Mix two-thirds ounce of white arsenic or Paris Green with 1 pound bran. Dilute one-sixth pint of molasses with a small amount of water and with this moisten the bran into a crumbly mass. Scatter along the rows of plants at night. For grasshoppers scatter broadcast before 10 a.m.
8. Dust with gypsum or hydrated lime (19 parts) and calcium arsenate (1 part).
9. Hand pick.
10. Dust with hydrated lime (5 parts) and calcium arsenate (1 part).
11. Spray with Bordeaux Mixture, 4-4-50 formula. This mixture can be purchased in the dry form from druggists or seedmen.
12. Spray with a solution containing 2 tablespoonsful of nicotine sulphate, 1 ounce soap, and 3 gallons of water, about every 10 days after insects appear.
13. Spray with Paris Green (1 ounce) water (3 gallons).
14. Spray with lime-sulphur solution (1 part) water (40 parts).
15. Rotate crops. Never plant corn following corn.

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to purchase 1-year-old plants for transplanting and where it is possible, select only the strong healthy plants. Many gardeners order a good many more plants than are needed in order to select the most vigorous, and with a cost of 1 to 2 dollars per 100 it is not expensive. For the average family 100 roots are all that are needed.

In planting, select a place in the garden that will not be disturbed by the plowing or preparation of the garden usually near a fence on the outside of the plot. The plants should be set out in furrow rows 3 to 5 feet apart, and about 10 to 18 inches between plants. The furrows should be 10 to 14 inches deep to permit proper covering of the roots. At first a shallow covering of 2 to 3 inches is desirable and as the plants grow, more soil can be worked in the furrow by cultivation so that by the end of the season the furrow is filled. Deep furrows can be made by running a hand plow in the same row 4 times. Planting should be made early in the spring of the year. Asparagus should not be cut for use until the third year after planting and then only for a short time.

A short-growing crop such as beans or early cabbage may be planted with the asparagus the first season, and cultivation of such a crop will also suffice for asparagus. After the first season cultivation should be shallow and frequent, all during the growing season.

It is a good practice to allow the tops to stand until spring, especially where the winter is severe. If the tops are cut green a good bit of the reserve food material is lost which should be stored in the roots. It is better to disc the tops into the soil in the spring rather than to burn them off. The crop is a comparatively heavy soil feeder and needs plenty of fertilizer, and from 10 to 12 tons of barnyard manure per acre each year may be applied when producing full yields.

The shoots are harvested by cutting with a knife after they have attained a length of 4 to 5 inches. The cutting should not be deep but just underneath the surface as there is danger of injuring the crown. If bleached asparagus is desired, the rows may be hilled up

with soil and when the tips appear thru the surface they are ready to cut.

Beans are an important crop in this state and are grown on a wide range of soil types. The heavier types are less desirable than light sandy loams. Beans will not stand light frosts and being tender should not be planted until all danger of frost is over.

The planting distance varies according to the method of cultivation used. For the small home garden, 15 to 18 inches between rows is satisfactory, while on the larger farm gardens, the rows may be 20 to 36 inches apart. The depth of planting should be from an inch to an inch and a half. Many gardeners plant beans thickly, around 2 beans per inch, in which case thinning is important. Garden beans should be thinned so that there will be a plant every 2 to 4 inches. Frequent shallow cultivation should be given up to the time the crop is in full bloom. Beans should not be cultivated when the vines are wet from rain or dew in order to prevent spread of diseases.

Lima beans require especially long, warm, growing seasons to do well and it is better to plant later than the snap beans. The seed are sensitive to proper conditions for germination and will not do well if the soil temperature is too low. With too much soil moisture they will rot. Any condition such as soil crust, due to rain after planting, will cause a heavy loss in stand. It is important that lima beans be planted on the lighter, sandier, soil types in this state, so they can mature earlier. This is especially true in sections of the state where the growing season is short. Care and cultivation are practically the same as for snap beans.

Pole beans are fast becoming more popular as a green shelled bean and may be planted in hills 3 to 5 feet apart. From 3 to 4 plants left in each hill are sufficient. The lima bean may also be used as a green shelled bean. See variety list for special varieties.

Beets.—Garden beets may be planted early in the spring before all danger of light freezes is over, since the crop is somewhat hardy. Beets will do well on a wide range of soil types. However, where bunch beets are desired, earliness is more important than heavy yield, and the lighter sandy soils are more desirable.

The seed may be sown with seed drills or by hand in rows 12 to 18 inches apart for hand cultivation or 20 to 24 inches apart when the horse-drawn drills are used. The seed should be planted to a depth of three-fourths of an inch to 1 inch under the soil, and where the crop is to be harvested all at one time, the plants should be thinned to from 3 to 4 inches apart in the row.

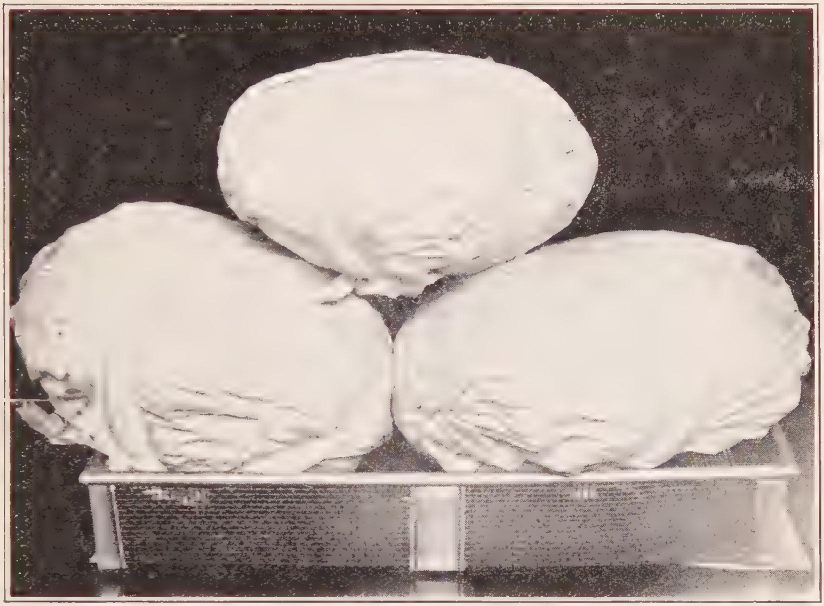
Thinning while small is very important since the beet seed is of a compound nature and several plants usually develop from one seed.

In leaving the largest beet in each bunch, quite an advantage is obtained in earliness. Successive plantings for winter storage may be made as late as the middle of July. Early planted beets usually are too large and woody to use for pit or cellar storage. Poor quality in the garden beet is usually determined by the light color or white ring zones in the interior of the root. A cross-section of the root should be dark red thruout. One of the desirable varieties is the Early Wonder, a round, early, dark red variety.

Brussels sprouts.

Brussels sprouts are very closely related to cabbage and require about the same cultural treatment. The sprouts or miniature heads are formed in the axils of the leaves and are cut off and cooked like cabbage. The crop is more hardy than cabbage, and usually reaches the best stage of edibility during late fall. The leaves should be broken off as the buds develop, and only a few left on the top of the plant. Plant lice are apt to feed in the young buds and a careful inspection should be made from time to time, so that spraying can be resorted to before the buds become large and act as protection for the insects.

Broccoli, closely related to cauliflower, is becoming better known, and the market is showing a promising development, especially in the eastern states. Test plantings over the state show that the crop is not well adapted to all sections because of the long season required for proper development. Broccoli requires about the same cultural treatment as cauliflower, except that the plants should be set farther apart and the wide space between rows. It has two advantages over cauliflower in that it is not as sensitive to high temperatures and it is more certain. Tying of the leaves is unnecessary, and a partial second crop is often cut. Broccoli should be cut before there are any signs of separation of the curd. At the present time it is difficult to secure seed of good strains, and many gardeners have been disappointed in the yields of the crop.



The flat Dutch variety of cabbage. A good type for winter storage.

Cabbage.—For the early crop, the seed should be sown in the hotbed in March and by proper hardening of the plants they may be set out in the field in April. The early varieties will mature in July and August. For the late crop the seed may be planted in an outdoor seedbed the latter part of May or first of June, and set out in the field as soon as they are of proper size. Late-planted cabbage should mature in October, and is usually ready for winter storage. The early crop is usually set 18 inches apart in the row and the rows 2 to 3 feet apart. Late cabbage is set at the wider spacing of 24 to 26 inches apart in the row and the rows are 3 feet apart.

The cabbage crop requires frequent cultivation, plenty of moisture and good fertilization for heavy yields. The crop will do well under a wide range of conditions, and is not sensitive to extremes of temperature.

Carrots.—The popularity of carrots has increased considerably during the past few years because their value in the diet is much better understood. They are included in most gardens, and usually planted at successive intervals of 2 or 3 weeks, so that a supply of fresh tender roots is available all during the growing season, and for winter storage.

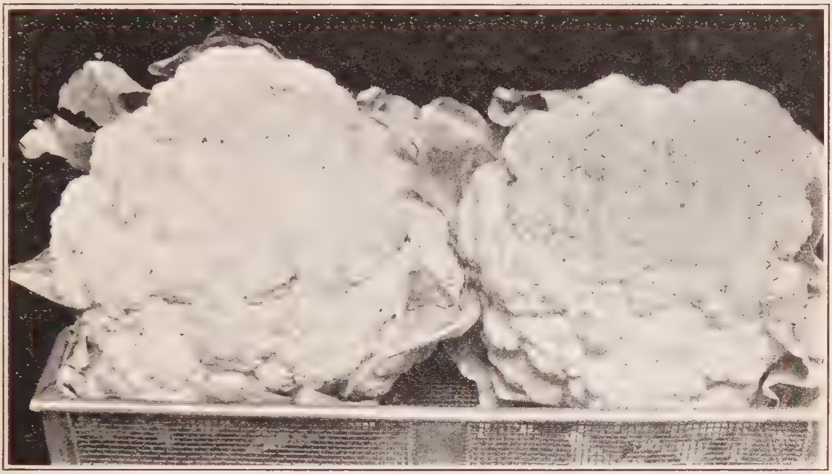
The crop is grown in about the same manner as garden beets. The seed is sown in rows 18 to 24 inches apart for the small garden and covered one-half inch deep. The plants should be thinned after they are well started, to a distance of 2 to 4 inches between plants. Thinning may be handled in the small garden by pulling the larger roots when of sufficient size to use, and allowing the smaller ones to develop. The smaller-sized carrots are tender and more desirable for table use.

Carrot varieties—Oxheart, Chantenay, Coreless and Danver's Half Long.

The most popular varieties are the Danver's Half-long and Chantenay. The Nantes or Coreless is a variety of very fine quality, altho it does not yield as heavily as the other two varieties.

Copenhagen market variety of cabbage. Cross section of two different heads, same age, showing undesirable core.

Cauliflower is a member of the cabbage family which has become an important crop, principally in the high-altitude sections of



Well-developed heads of cauliflower.

the state. It does not thrive well in dry or hot weather and for the sections with long growing seasons, it should be planted either as an early spring or late fall crop. For the early crop the seed should be planted in hotbeds in March and as soon as severe freezes are over the plants should be set in the field. Cauliflower will not stand as much frost as cabbage. The spacing and distance between rows varies according to the variety, as a rule, 18 inches between plants and 3 feet apart in the rows, being the common planting distance. The late crop may be started by planting the seed in the open during May and by July the plants should be large enough to set in the field.

As soon as the head or curd has started to form, the leaves should be tied over the top, in order to properly bleach the curd. Many gardeners use different colored string in tying heads so that all of the first-matured plants are tied with one color and can then be harvested without any difficulty or loss of time. The most common variety for the main crop is the Early Snowball. Another new, promising, early variety is the Matchless Spring.

Celery will do well on a deep, rich, well-drained soil. The heavier-type soils are more often used to produce celery. However, where there is plenty of moisture available during the growing season, good crops may be produced on the well-fertilized lighter-soil types. Plenty of fertilizer should be applied to the soil for celery growing

Transplanting celery. Notice the method used in irrigating before and after setting.

and where available, barnyard manure is the most satisfactory. It is better to turn manure under by spading or plowing in the fall of the year.

Growing celery plants is rather an exacting operation and it is better for the home gardener to buy plants rather than attempt to raise the necessary number. It is important in sowing celery seed that the soil be very fine and well pulverized because of the small size of the seed, and the slow germination. The seeds should be covered lightly with soil after sowing and the seedbed shaded until the sprouts are well thru the surface. Planting for the early crop should be done about March 1 and the plants should be ready to set out in the field during the first half of May. Late celery plants are often started out of doors and set out in the field in early July.

In setting the plants in the garden, it is important to set them at the proper depth along the edge of the furrow so that the heart of the plant is not covered. The rows should be made at the proper distance and the water run thru the furrow considerably ahead of setting. The plants may then be set along the side of the furrow and the water again run thru the row. A dibble or a trowel may be

used in making an opening in the soil for the plants. Frequent and shallow cultivation is important where a manure mulch is not used, in cutting down moisture losses.

A winter storage trench for late celery.

The early varieties are blanched by wrapping each individual plant with paper or by placing boards along each side of the row close to the plants. Time required for blanching depends upon the variety and weather conditions; it usually takes about 2 weeks for proper blanching. The late celery is bleached by gradually banking up earth in the row. For storing, best results are secured by placing the celery in outdoor trenches. The depth of the trench depends on the height of the celery, usually about 18 to 24 inches deep, so that some of the top of the plant is left above the trench. The crop should not be stored until continuous cold weather sets in. The plants should be dry, free from disease, and the roots must not be removed when stored, so that the plants will continue to grow slowly. The top of the trench may be covered either with boards or with strawy manure. Cellar storage is not generally satisfactory.

There are several new early varieties that are being used to some extent, the Easy Blanching and Golden Plume, altho the commercial acreage is still planted to the Golden Self Blanching.

The cucumber is a tender vegetable which cannot be planted until after all danger of frost is over. As a rule the rows are laid out, on all the larger acreages, 6 feet apart and the seed planted in hills 18 inches apart. A good many gardeners follow the practice of sowing the cucumber seed in the row in a small drill or by hand and thinning out, after the stand is thru the ground, to a distance of 2 to 3 feet apart, leaving 3 to 4 plants in each hill.

The crop will do well on well-fertilized, light, sandy loam. It is important that the soil be rich and have plenty of available plant food. In planting in the small garden, a small fork full of manure

may be placed under each hill and mixed in with the soil. The seed should be covered to a depth of about one-half inch. Clean cultivation should be kept up until the vines run across the rows.

Cucumbers are picked for slicing as soon as they have reached the proper size. This lengthens the bearing period and considerably increases the yield of cucumbers. In case the cucumbers are to be used for small pickles, they should also be picked when they reach the proper size. Usually, the smaller the fruit the more desirable for the small pickle.

The egg plant requires a long, warm growing season with a rather light loamy soil to develop properly. In most sections of Colorado the season is too short for the egg plant to properly mature without transplanting. The seed should be planted in the hotbed or greenhouse around the middle of March and they may be either transplanted to small pots when they develop to two small leaves, or they can be set directly out in the field, provided weather conditions will permit. Egg plants are very susceptible to frost injury and they should be properly hardened off in the coldframe before setting out in the field. In setting out, they should be planted in rows 3 feet apart and about 20 inches between plants. Closer spacing may be given if space is limited. It is important to keep crops growing uninterruptedly during the season, and the soil should be rich and well fertilized for good yields.

The most common variety is the Black Beauty. For the small,

Kohl-Rabi. A vegetable deserving more attention by gardeners.

home garden, better results will be secured by purchasing plants from a seed house or nursery company. The plant is only adapted to the sections of the state where the growing season is long.

Kohl Rabi is a member of the cruciferae family and is closely related to the cabbage group. It produces a thickened stem or bulb just above the ground and has a flavor very similar to cauliflower. The plant is hardy and can be grown under practically the same conditions as cauliflower. The seed may be sown directly in the field for the late fall crop or for the early spring crop it may be planted in the hotbed and transplanted to the field as early as April. The plants should be thinned out when the seed is sown in the field, to a distance of 6 to 8 inches apart.

This crop only remains in an edible condition for a short time and it should be used when the bulb reaches a diameter of 2½ to 3 inches. After that time it becomes woody and strong and is unfit for table use.

Head Lettuce.—Head lettuce is one of the most important commercial salad crops grown in the state and can be grown under a wide range of soil conditions. It can be grown on a rich, moist soil and is especially well adapted to the high-altitude sections of the state. It is also an ideal crop to grow early in the spring or late in the fall in the sections of the state with a long growing season. Good results have been secured by planting the seed in the hotbed in March and transplanting the lettuce to the field in April. However,

Head lettuce grows to perfection in the high-altitude sections of the state.

the majority of the acreage is planted by seeding directly in the field. Plantings may be made in July and August for the fall crop as lettuce will stand considerable low temperature.

Lettuce should be grown without any checking in the field to be of high quality. Rapid growth is especially important and the soil should be rather rich for good results. The seed is usually sown in rows about 18 inches apart and thinned out at a distance of 12 to 14 inches in the row. The seed is very small and should not be planted deeper than half an inch. It is important to cultivate frequently and at a shallow depth.

The crop is sensitive to weather conditions and especially so during the period that it is heading. Frequent light rainfall during the heading stage will produce soft mushy heads, whereas unusually dry hot weather will favor the development of seed stocks. For that reason it is important that the crop be matured as rapidly as possible before there is danger of extremely hot weather starting in.

For head-lettuce varieties, the more common one now being used in the large commercial acreages in the state is New York or Wonderful. It is also known as the Los Angeles Market and Mountain Iceberg. The gardener should emphasize the variety that he wants to plant and should not ask for the common Iceberg type. This variety has a pink tinge on the margin of the leaf and is undesirable for planting.

Leaf Lettuce.—Leaf lettuce is often grown in home gardens for use in salads. This type of lettuce is almost a sure producer and will yield an ample supply of greens for the average family. When it is grown in the small garden it is usually not thinned, but cut or thinned out as it is used. The culture is practically the same otherwise as for the growing of head lettuce.

For more details concerning the culture of lettuce, write to the Colorado Experiment Station and ask for Bulletin No. 309, entitled "Head Lettuce, Cauliflower and Peas."

Muskmelons.—The term 'muskmelon' as used by the grower refers to the melons that are characterized by large seed cavities, distinct ribbing and a surface that has a rather light netting, whereas the cantaloupe usually has a small seed cavity and is heavily netted on the surface. The muskmelon is an important commercial crop in this state and is grown principally in the sections which have a long, warm, growing season.

In order to produce it profitably in the sections with short growing seasons, it is important that it be planted on a light, sandy, loam, soil type, preferably with a southern slope. The soil should be well prepared, free from cloddiness, and not too heavily fertilized.

For the small home garden the seed is usually planted in hills 5 to 7 feet apart and 6 to 8 seeds planted in each hill. The seed is planted to a depth of about 1 inch. After the sprouts have appeared thru the surface of the soil they should be thinned out to 3 or 4 plants per hill. The plant will not stand even the very light freezes and seed should not be planted until all danger of frost is over.

Where the growing season is especially short, cantaloupes of the early variety may be grown by starting indoors by planting in small strawberry boxes or flats. After the plants have developed 2 or 3 true leaves they can then be set out in the field and a plant protector placed over the top of them. The use of such protectors has proved to be very profitable in many instances for the small garden.

Cultivation should be frequent and shallow up to the time the vines run across the row. Light frequent irrigations are recommended for this crop; the nature of the vine growth causes the soil to be more or less shaded and it will retain moisture for longer intervals.

Muskmelons or cantaloupes should not be pulled for immediate consumption until the fruit separates from the stem. In commercial fields the picking is accomplished by pulling the melons from which a fourth of the stem is pulled off of the fruit. This is called the quarter-slip stage and is used for long-distance-shipping purposes. For the shorter-distance shipments the half-slip stage is used, and for immediate consumption the full-slip stage is used and that is where the entire stem pulls out of the melon.

There is much confusion among growers as to varieties. However, the larger commercial acreages are planted to Hale's Early and to the Pollock 10-25. The Pollock 10-25 is the main crop variety and is a heavy yielder of high-quality melons. A very good variety of muskmelon is the Greeley Wonder.

Onions.—The growing of onions in this state has proved to be an important industry in the sections of the state with long growing seasons. They can be grown in practically all parts of the state, even tho the growing season is short, by using the transplanting method. The crop may be grown from seeds, plants or sets. Where the sets are planted the crop is usually harvested as green onions, whereas, in planting seeds and plants, mature dry onions may be grown for the market. The seed is usually sown during the latter part of March or the first of April, in single rows 20 inches apart. In many cases the rows are planted at a distance of 26 inches apart and a row planted on each side of the furrow. This leaves a pair

of rows about 12 inches apart and 14 inches between rows. A good bit of the commercial acreage is planted, however, in single 20-inch rows.

Onions are ready to harvest when most of the tops drop over from maturity.

In planting seed of good quality it is seldom necessary to thin where the seed is evenly distributed in the row. In some cases it has been necessary to thin and this was caused by too heavy seeding, in which case the plants should be thinned out to a spacing of 4 inches. The seed should not be covered at a depth of over half to three-fourths of an inch.

The root system of the onion crop is usually very shallow and irrigation should be frequent. Where the seed is planted it is often necessary to irrigate after planting. While no definite rule can be laid down for irrigating onions, it is important that they be kept growing without checking.

In sections of the state where the growing season is unusually short, a good yield of onions may be secured by the transplanting method. In using this method the seed is sown in the hotbed or in the small greenhouse bench during February. As a rule there are somewhere around 10,000 seeds per ounce and it will require around 8 ounces to grow the 80,000 plants necessary to set an acre. The plants should be grown to the size of an ordinary lead pencil before

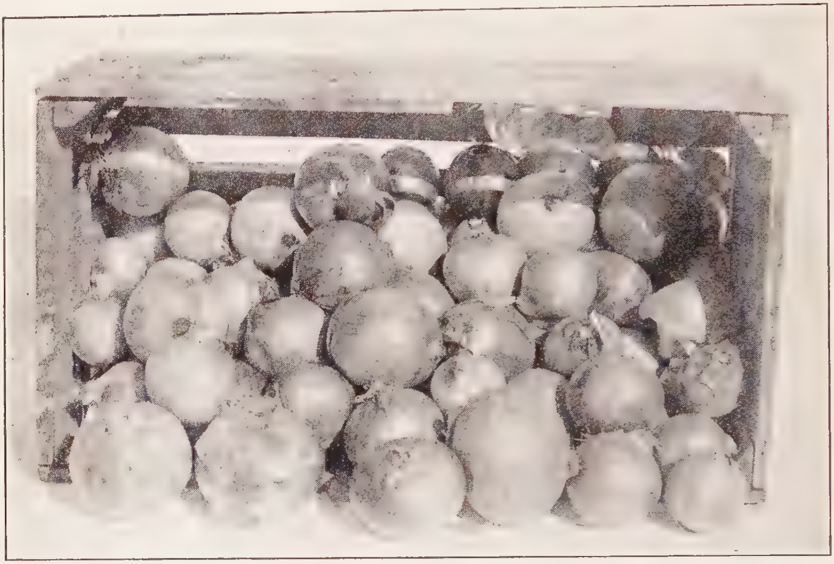
they are removed for transplanting. It is important that the top development be held down so that there is not a soft, succulent growth made. The plants should be hardened off gradually by withholding water and lowering the temperature. Plants set in the field are usually spaced at a distance of 3 to 5 inches in the row and planted in 20-inch rows. There are several advantages of using this method.

It lengthens the growing season, it favors the development of a milder, more mature onion, increases the yield and eliminates the tedious process of weeding. The first hoeing or weeding of onions is usually the most expensive and this can be done by cultivating before the onions are transplanted. The cost of setting plants varies between $40 and $65 per acre and at the present time the department is conducting comparative costs on the two methods. There are a good many transplanting machines on the market, which, while they have not been tried out experimentally are supposed to plant from 60,000 to 80,000 in a day. Ordinarily one man can set from 8,000 to 10,000 plants in a day. The transplanting method so far has not proved to be well adapted for extensive commercial use. However, for the small home garden it should be especially profitable in growing the mild Spanish or Bermuda onion.

When the onions are matured properly the tops will fall over naturally and the crop is then ready to pull and cure. The bulbs are pulled from the soil and piled in windrows, usually 6 rows to the windrow, and allowed to cure. The tops are cut off about 1 inch above the bulb and allowed to dry for a period of 10 to 14 days. It is important that the bulbs be well cured so that the necks are not green when they are put into storage. All immature or thick-necked specimens should be sorted out and only the very choice bulbs selected for storing. Onions should be stored preferably in crates in a cool, well-ventilated, dry room.

In growing onions for sets, the gardener sows the seed very thickly so that the onions do not have a chance to develop. A good many gardeners use a small portion of their plot for the growing of sets for the next year. As soon as the small plants have reached the size of one-half to three-fourths inch in diameter, they should be pulled and dried in the sun before topping. The small sets thus procured can be prevented from sprouting by placing in a cool, dry, well-ventilated room and can be kept dormant until ready to set out.

The parsnip is a crop that will do well on especially deep, sandy-loam soil. The root development is unusually long and it is important that the soil be deep. This crop requires a long season for



Well-matured onions will keep better when stored in open-slat crates.

full development and the seed should be planted at a depth of not less than one-half of an inch, in rows 18 to 24 inches apart. As soon as the crop is well started it should be thinned to a spacing of 4 inches between plants. The crop is unusually hardy and a portion of the crop may be harvested in the fall of the year and placed in a convenient storage pile or cellar and the balance left in the ground until spring. The portion that is left in the soil should be covered with a mulch manure or the soil thrown over the top of the crowns.

Potatoes have an important place in the home garden from two standpoints. They will supply new potatoes as early as June in some sections and not later than August in any part of the state. Second, they will keep well into the winter or even into the following summer under proper storage conditions. They yield more food for a given amount of space than most any other vegetable and can be grown on a small scale anywhere in the state.

Potatoes succeed best on a sandy-loam **soil**, underlaid with a porous sub-soil, but even the heavier soils produce good crops if they are underlaid with a porous sub-soil. Heavy adobe soils which puddle easily are not suited to potatoes, unless they can be loosened up by the application of well-rotted manure in large quantities.

The **preparation of the soil** should be thoro and deep, to conserve moisture, provide a large feeding area, and to insure the least resistance to the developing tubers. The worst enemy of the garden

A mountain potato field. Potatoes can be profitably grown in the home garden.

potato is scab. This difficulty is caused and increased by growing the potatoes on the same plot year after year and by the application of fresh manure. Other diseases, such as rhizoctonia and fusarium may also be carried by the soil. Because of these diseases the potato plot should be moved around over the garden and not remain in the same place year after year. In fact, the potatoes should not remain in the same spot 2 years in succession.

For garden purposes the **early varieties** are recommended: Bliss Triumph, Irish Cobbler and Early Ohio. In some cases, under irrigation, a **late variety** may be desired in which case the standard variety for the locality will be best or the Rural New Yorker No. 2 will succeed almost anywhere if the season is long enough.

As a general rule the home gardener does not receive maximum returns from his potatoes because the seed is badly run out or degenerated. He should procure new certified seed at least once in 5 years and in some localities once in 2 years. It is always advisable to treat the seed and for this purpose one of the organic mercury compounds will be found suitable.

The seed should be cut into large blocky pieces averaging at least 2 ounces in weight. It is best to cut the potato longitudinally from the bud eye cluster to the stem and then cut straight across if necessary, making sure that there is at least one eye on each piece.

The best plants and the best tubers should always be saved for seed. Do not plant the culls that are left in the spring.

It may be advisable to make **two plantings** in sections with the longer growing seasons, one to supply new potatoes during the latter part of the summer and one for the winter storage supply. In the warmest sections, planting may be done the last week in March or early in April. In the highest altitudes it may not be possible to plant until nearly the first of June. The planting may be done by hand. A furrow or trench is opened up to a depth of 4 or 5 inches depending on the character of the soil. In heavy soil planting should not be over 4 inches deep, while in light soil, 5 or even 6 inches is better. If the garden is irrigated, plants may be 12 or even 9 inches apart and rows 28 inches apart if hand cultivated or 34 inches apart if horse cultivated. On dryland plants should be from 14 to 18 inches apart and rows 42 inches apart.

Cultivation should begin soon after planting to keep the weeds down and keep the soil loose and well aerated. After the plants are up, cultivation should be continued between the rows. Thoro cultivation should follow each irrigation and under no conditions should the soil be allowed to crust or bake. As soon as the tubers begin to form, soon after blooming, dirt should be drawn to the plants.

Potatoes should always be **irrigated in furrows** 6 to 8 inches deep between the rows, never by sprinkling. The water should be allowed to run until it has wet thru between furrows, 12 to 48 hours. A small stream of water for a longer time is better than a larger stream. Most gardeners irrigate potatoes too much; 2 to 4 irrigations will generally be sufficient. Keep the plants growing and do not check them by letting them get too dry or by getting them too wet.

Small new potatoes may be dug 8 to 10 weeks after planting.

Peas.—The growing of peas is of considerable importance in the state, both in high-altitude sections for the fresh-vegetable market and for canning, in the northern part of the state. The drawf round-seeded varieties are usually the earliest and most hardy but are not of high quality. For the small home garden the crop is usually planted in double rows 18 to 24 inches apart or in single rows 24 inches apart. The seeds should be planted to a depth of about 1 inch for late seeding and 3 to 4 inches for early planting, which may be done as early as the ground can be worked. The crop requires a cool growing season and best results will be secured by planting so that the crop will mature either early in the spring or late in the fall. The crop responds favorably to fertilization and over-fertil-

ization will produce an unusually heavy fine growth at the expense of pod production. For the home garden successive planting should be made during the early spring and late summer.

The dwarf varieties are becoming more popular and do not need trellis supports. For the tall varieties the trellis is usually needed to support the vines and the successive planting should be made only with the dwarf types. For more detailed information concerning the culture and growth of peas, write to the Colorado Experiment Station for Bulletin No. 309, "Lettuce, Cauliflower and Peas."

Peppers.—The pepper crop usually requires a long, warm growing season, slightly more so than the tomato crop. The seed is slow to germinate and it is especially sensitive to too much water while sprouting. Plants should be started in the hotbed or greenhouse in early March in order to have good strong vigorous plants to set out in the field when danger of frost is over. Due to the slow growth made by the plants, they are often transplanted once to pots or flats before setting out in the field. The plants may be set out in the garden in the latter part of May or early June as soon as all danger of frost is over. The distance for setting in the field is usually in rows 18 to 24 inches apart, and about 15 inches between plants.

Sweet corn requires an unusually warm growing season for proper development and has more limited use in this state because of the short growing season, especially in the high altitudes. For the small home garden, corn is usually planted in rows 30 to 36 inches apart and the seed planted so that there will be a plant every 10 inches in the row.

Another method often used is planting the hills in rows 3 feet apart and 3 feet apart in the rows. The seed should be planted at a depth of an inch to an inch and a half. It should not, however, be planted until the latter part of May, after danger of frost is over.

Some gardeners follow the practice of making successive plantings during the summer in order to have a fresh supply on hand during the summer season. This can be done profitably in sections of the state where the growing season is long.

In order to have proper quality in sweet corn it should be used a few hours after picking.

There are a few new varieties which will mature in 60 to 65 days. However, varieties like Golden Bantam usually require 70 to 75 days. In the sweet-corn variety trial, results do not warrant the use of the smaller 60-day corn.

It is not necessary in growing sweet corn to sucker the sprouts

that grow up from the base of the old plant. Over a period of years it has been shown that suckering sweet corn does not pay. It is very difficult in planting the later varieties to secure proper maturity and it is better for the home gardener to make successive plantings of varieties like the Golden Bantam rather than to grow the Country Gentlemen or Late Evergreen types.

Radishes.—The easiest and quickest vegetable to mature in the garden is the radish. In order to secure quality and flavor in the radish it is important that a rapid growth be made without any check. The seed should be planted at a depth of about half an inch and the crop may be planted in rows 12 to 20 inches apart. Some of the early varieties will mature in 25 days and successive plantings should be made during the cool season. Radishes will not do well if planted in the heat of the summer, and it is much better to make successive early spring plantings and successive late plantings.

This crop is an ideal one for a companion crop with lettuce, or it may be sown between the rows of cabbage, beans and potatoes. Because of the short time required for maturity it is usually out of the way before heavy cultivation is needed by the other crops.

In pulling the larger radishes, thinning is thus accomplished and more room is given for the others. In planting in the hotbed, the seed is usually sown in rows 4 to 5 inches apart early in the spring. When forced in this manner the crop will mature in a short time.

In growing the winter radish, one should sow the seed about the last of July or the first of August. This will permit the root to develop to a sufficient size for storing in pits or in the cellar. The size, shape and color of radishes should determine the one that the grower wishes to plant. Referring to the variety list, a few of the more common types are listed.

Spinach is being grown more extensively every year and is used as a greens crop. It is very hardy and can be planted early in the spring in rows 12 to 20 inches apart and thinned out when ready for use. It requires around 50 days for the crop to properly mature. Successive plantings may be made during the growing season and the late crop may be planted in July or in August. Spinach should be planted in a soil that is rich and well fertilized so that a rapid growth can be made. There should be plenty of moisture available during the growing period, as an especially dry period often causes checking and injures the quality of the leaf.

The turnip is a hardy vegetable and may be grown as an early spring or late fall crop. The seed may be planted in early April for the spring crop or in August for the fall crop. The rows for the

small garden may be marked off for planting at a distance of 18 to 24 inches apart. The seed should be sown half an inch deep and the stand thinned to a distance of 2 inches apart in the row for harvesting as a bunch vegetable. Turnips are hardy and may not be harvested in the fall until after light frosts. The roots may be stored in outdoor pits or in cellars.

Tomatoes pruned to a single stem will produce earlier tomatoes.

Tomatoes require from 100 to 150 days to produce fruit and if an early crop is desired, the seed should be planted 6 to 8 weeks before the date of the last killing frost in the spring. For the small home garden this can be accomplished by planting the seed in the house in shallow boxes and as soon as the seedlings reach a height of 2 inches, they should be hardened by gradually withholding water and lowering the temperature for about 2 weeks before setting out in the field. The seed may be planted about the middle of March for the early crop. The plants are usually set out about 3 by 3 feet apart. They should be set deep, the soil firmly pressed around the roots, and watered immediately after setting.

Pruning the plants to a single stem will produce earlier tomatoes and is especially adapted for use in the dryland sections of the state. The pruning is accomplished by the pinching off of all branches or shoots in the axils of the leaves so that the fruit and leaves are produced on a single stem. The yield is usually not as great on pruned plants, altho there is an advantage in earlier ripening, more convenience in picking and in controlling insects and disease by spraying.

The variety to select for planting depends upon the use the gardener plans to make of the fruit. For the family table as a fresh vegetable, quality, type and earliness should be considered. For

canning a variety such as the Bonny Best, will do well as it has a good red color, is smooth, has but little waste of fruit and is a good yielder. The Marglobe is a disease resistant variety and should be planted if there is a wilt disease prevalent.

Pumpkins and Squash.—The cultural treatments for pumpkins and squash are practically the same. The bush varieties may be planted in hills 4 feet apart. These two crops will respond to fertilizer treatment and a fork full of well-rotted manure under each hill will pay well in yield returns. The seed should not be planted until all danger of frost is over, and the soil is warm.

Summer crookneck and white marrow.

The Table Queen variety of pumpkins, often called Acorn or Des Moines, is one of the new types which is becoming very popular. It can be used during the summer or winter months, and because of its small size may be halved and baked. One pumpkin will do for two individual servings.

The early summer varieties are in prime condition to pick just before the shell begins to harden. If the skin can be broken by a slight pressure it is in an edible condition. A hard shell is undesirable. The later squash as the Hubbard, should, however, have a hard shell when mature and ready to pick for use or storage.

Forced heads on roots of Witloof chicory.

Witloof Chicory.—Chicory is often known as French Endive, and is grown mainly for its leaves used in salads and its roots used as an adulterant for coffee. The seed is usually planted in June in 18 to 30-inch rows, and thinned at a distance of 4 to 6 inches apart. In the fall the roots are plowed out and tops cut off to about 3 inches above the crown, and placed in storage until ready to use for forcing. The crop may be forced by placing in a cool cellar or under greenhouse benches. The roots are vertically set in a trench close together and covered with fine soil or sawdust to a depth of 7 to 8 inches, so that light is excluded. This will prevent the leaves of the head from spreading. Light watering is necessary and under temperatures of 50 to 60 degrees the heads should develop to proper stage in 4 weeks. The heads should be cut before becoming too long, or just before pushing thru the covering.

Rhubarb is a perennial plant that is ready for use early in the season. It will do well on a wide range of soils, and requires plenty of fertilizer for good yields. It can be propagated by division of the roots in the spring or fall of the year, and each piece should have one strong bud. The roots should be covered after planting to a depth of 3 to 4 inches. The roots may be spaced 18 to 30 inches apart in rows 3 to 4 feet apart. Harvesting should not start until 2 years after planting. The crop requires plenty of water, and growth should be maintained after the cutting season in order to store food in the roots for the growth the following spring.

Watermelons.—The culture of the watermelon is the same as described for cucumbers and muskmelons. The spacing of the plants is wider and the hills should be 8 feet apart each way, with 4 plants left in each hill. The crop is easily injured by frost and should not be planted until after the date of the last frost in the spring.

Vegetable Varieties for Colorado

Asparagus	Mary Washington—(Rust Resistant) Palmetto Columbia
Dwarf Snap Beans	Giant Stringless (Green) Stringless Refugee (Green) Pencil Pod Wax Refugee Wax Stringless Greenpod
Bush Shell Beans	Dwarf Horticultural
Pole Shell Beans	White Kentucky Wonder
Bush Lima Beans	Henderson Bush
Beets	Crosby's Egyptian Early Wonder Long Season Detroit Dark Red Early Model
Broccoli	Italian Calabrese
Cabbage	Golden Acre—Early Copenhagen Market—Early Enkhinzen—Midseason Danish Ballhead—Late Flat Dutch—Late
Carrots	Nantes—Coreless Chantenay Danver's Half-Long
Cauliflower	Early Snowball Dwarf Erfurt Matchless Spring (Extra Early)
Celery	Golden Self-Blanching (Early) Easy Blanching Giant Pascal
Sweet Corn (Early)	Golden Bantam (Yellow) Gills Early Market (White) Banting (Yellow) Sunshine (Yellow)
Sweet Corn (Midseason)	Howling Mob (White)
Sweet Corn (Late)	Evergreen Bantam (Yellow) Country Gentlemen (Late White) Stowell's Evergreen (Late White)
Cucumbers	Davis Perfect (Slicing) Long Green Boston Pickling (Pickling) White Spine
Egg Plant	Black Beauty
Kohl-Rabi	White Vienna
Lettuce (Heading Type)	New York or Wonderful (Main crop in state—crisp head type) Wayahead (Butterhead) Mignonette—Small crisp heading (early)
Lettuce (Leaf)	Grand Rapids
Cantaloupes and Muskmelons	Hale's Early Hearts of Gold Pollock (10-25) Honey Dew Honey Ball Greeley Wonder
Onions	Ebenezer—for production of sets Danver's Yellow Globe Mountain Danver (Main crop) Prizetaker Sweet Spanish or Valencia (Main crop) Denia Gibraltar
Parsley	Moss Curled
Potatoes	Early Ohio Triumph Cobbler Rural New Yorker
Parsnips	Hollow Crown Guernsey

Peas	Laxton's Blue Bantam Dwarf Perfection Nott's Excelsior Dwarf Telephone
Peppers	Long Red Cayenne (Hot) Harris Earliest Panama (Piemento) Sunnybrook Oshkosh
Pumpkin	Small Sugar Summer Crookneck or Summer Straightneck Table Queen or Des Moines Early White Bush Scallop
Radish	Early Scarlet Globe French Breakfast White Icicle Long Scarlet Black Spanish (Winter radish)
Spinach	Long Standing Bloomsdale (Early) Juliana King of Denmark New Zealand (Late)
Squash	Delicious Hubbard Prolific Marrow Hubbard Kitchenette
Sweet Potatoes	Yellow Jersey Nancy Hall
Swiss Chard	Fordhook Giant
Tomatoes	Earliana (Early) Early Jewel Bonny Best Marglobe (Wilt Resistant) Greater Baltimore Globe Stone Ponderosa
Turnips	Purple Top Milan Red Top White Globe
Watermelon	Kleckley Sweet Tom Watson Fordhook Early

Harvesting

The time to harvest vegetables in order to secure high quality, is largely determined by the stage of growth. Quality in vegetables is of importance to the home gardener and it varies widely according to the kind of crop grown, weather conditions and cultural care given during the growing of the particular crop

Peas, sweet corn and snap beans lose quality quite rapidly after harvesting and should be used as soon as possible after being removed from the plants Harvesting should not be delayed until they have reached full size, as there is a considerable lowering of the quality by the delay. There is no definite rule to follow in harvesting for the highest stage of edibility Experience is of value in this connection.

The root crops, such as radishes, carrots, beets and turnips, should be harvested when small, for quality. There is a definite relationship between size and quality, the smaller the root the higher the quality.

During periods of hot or wet weather, head lettuce will become worthless in a short time and it should be harvested as soon as heads are firm and compact. Cauliflower will also deteriorate rapidly and the heads should be cut as soon as they are of good size and well blanched.

Cabbage and celery will stand some frost but should be harvested before severe weather sets in. Potatoes must be dug before there is danger of tubers freezing. Parsnips may be left in the soil all winter and harvested in the spring, altho it is advisable to have a small quantity in storage for use during the winter.

Storage of Vegetables

There are many vegetables which can be stored profitably for use during the winter months, and there is less work and expense involved in storing than in canning or drying. It will assure a fresh supply of vegetables during the winter and will reduce the grocery bill.

Root Crops.—Root crops that can be stored easily are potatoes, beets, carrots, parsnips, winter radishes, kohl rabi and rutabagas.

In selecting roots for storage, discard (1) immature roots, (2) large overgrown specimens, (3) irregular and sprangly shaped roots, (4) cut and bruised roots. Select the medium-sized mature roots. In cutting the tops off, be careful that the cut is not close to the root. All root crops require about the same storage conditions and can be stored together. The storing should not be done until late fall, so that the vegetables have ceased to grow. Miniature roots will not keep well and the large specimens are apt to be tough and woody.

There are four types of storage that may be used, depending on the quantity to be stored, namely: (1) Outdoor pit, (2) outside cellar, (3) house cellar, (4) commercial storage cellar. The outside pit cellar is a good one for the home gardener to use.

1. **Outdoor Pit.**—Take surface soil off to a depth of 6 to 8 inches, in shape of rectangle. Place a thin layer of straw on inside edges of the excavation. The roots are then placed in a pyramidal form. The width of excavation should be 4 to 6 feet and the length as long as is necessary for quantity to be stored. Cover piled vegetables with straw 12 to 18 inches thick. Cover with 2 or 3 inches of soil at first, then 4 to 6 inches in proportion to the approach of cold weather. For ventilation, after first storing, make an opening at the base, and one at the top to permit circulation of air. When cold weather sets in, cover ventilators. This method is used for storing large quantities, where the grower wishes to keep them until spring.

A large barrel or heavy box may be placed in the ground in such a position as will make it convenient to get into during freezing weather. A pit may be dug so that the barrel or box can be placed in a semi-horizontal position. The box can be covered with a lid or the barrel with the barrel head. The container may be covered with straw and dirt in sufficient layers to protect the roots from freezing. This is a handy method of storing small quantities of root crops, and can be used in any small backyard garden.

2. **Outside Cellar.**—Provide boxes of sufficient size to hold quantity of vegetables desired. In the bottom of the box place a layer of fine moist sand (not wet), 2 inches deep. Place a layer of vegetables and then another layer of sand about 1 inch deep. Continue until the box is filled. Place box in a cool cellar. When the top layer of sand shows signs of drying out, sprinkle it with water to keep it moist.

3. **House Cellar.**—Vegetables may be stored loose in bins in the cellar, when large quantities are stored. Air in the cellar must be kept moist, properly ventilated and the temperature right. Vegetables may be stored in piles and covered with moist sand if there is sufficient room in the cellar and the temperature can be kept low.

Celery Storage.—Trench Storage.—Dig a trench about 1 foot wide and as deep as necessary so that the tops of the stalks are close to the surface of the ground. The plants should be pulled with most of the root system left on, and set vertically and close together in the trench. The top of the trench can then be covered with straw or strawy manure. Some gardeners nail two 1-by-12-inch boards together to form a trough and invert this over the trench. The roots of the plants in the trench should be set in moist soil so that there will be some growth made during the storage period. Store the celery that is free from disease.

Cabbage Storage.—Pit Storage.—The cabbage plant is pulled with the roots attached, and after removing a few of the outside leaves the head is placed down in the trench. The trench is about 6 to 8 inches deep and wide enough for 3 or 4 heads and as long as necessary. On top of the first row of heads placed in the trench, 2 more rows may be placed between the stems of the first row. A layer of straw is put over the cabbage and a layer of soil placed on top of the straw. More soil may be added as the winter weather becomes more severe. Small quantities may be stored in a cool cellar. It is important that the temperature be kept low.

Onion Storage.—1. Store only mature, well-cured, bulbs (very important).

2. Require plenty of ventilation, store in shallow boxes or crates not over 3 or 4 layers per crate.
3. Temperature should be around 32 to 40 degrees F. High temperatures are undesirable.
4. Air should be dry.

Squash Storage.—Store well-matured individuals. Test maturity by hardness of the shell. When impossible to dent the shell with thumb nail, they should be all right for storage. They require warm temperature and dry air. Temperature 60 to 80 degrees F. The furnace room is a good place to store squash.

Pumpkin Storage.—Pumpkins require cool, medium-moist air, and rot easily if too warm or if the air is too moist. Temperature 40 to 60 degrees F. Too dry air makes pumpkins shrivel. Do not pile in cellar; place on shelves, same as with squash.

Acknowledgment

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List of Available Bulletins of Interest to Vegetable Growers

Colorado Experiment Station, Fort Collins, Colorado.

- No. 278—Degeneration in Colorado Potatoes.
- No. 309—High-Altitude Vegetable Growing (Head Lettuce, Cauliflower and Peas).
- No. 311—Tipburn of Lettuce.
- No. 312—Harvesting and Marketing Cantaloupes and Honeydews.
- No. 314—Potato Growing in Colorado.
- No. 321—Soil Sterilization for Seedbeds and Greenhouses.
- No. 323—Common Diseases of Colorado Truck Crops.
- No. 328—Hotbeds and Coldframes.
- No. 331—Some Edible and Poisonous Mushrooms of Colorado.

Colorado Extension Service, Fort Collins, Colorado.

- No. 121 —Farm Storage of Apples and Potatoes.
- No. 163A—Marketing Colorado Cabbage.
- No. 208A—Potato Seed Selection.
- No. 300A—Small Fruits, Raspberries, Blackberries Currants and Gooseberries.
- No. 303A—Lawns.

Division of Agriculture, U. S. Department of Agriculture, Washington, D. C.

Farmer's Bulletin No. 204—The Cultivation of Mushrooms.

Farmer's Bulletin No. 220—Tomatoes.

Farmer's Bulletin No. 289—Beans.

Farmer's Bulletin No. 345—Onion Culture.

Farmer's Bulletin No. 433—Cabbage.

Farmer's Bulletin No. 829—Asparagus.

Farmer's Bulletin No. 879—Home Storage of Vegetables.

Farmer's Bulletin No. 937—The Farm Garden in the North.

Farmer's Bulletin No. 1044—The City Home Garden.

Farmer's Bulletin No. 1269—Celery Growing.

Farmer's Bulletin No. 1242—Permanent Fruit and Vegetable Gardens.

Farmer's Bulletin No. 1291—Preparation of Fresh Tomatoes for Market.

Farmer's Bulletin No. 1325—Marketing Onions.

Farmer's Bulletin No. 1594—Preparation of Bunched Beets, Carrots and Turnips for Market.

Farmer's Bulletin No. 1563—Cucumber Growing.

Farmer's Bulletin No. 1609—Lettuce Growing.

Department Bulletin No. 1427—Dryland Gardening at the Northern Great Plains Field Station.

Technical Bulletin No. 75—Crop-Plant Stimulation with Paper Mulch.

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HOG CHOLERA AND ALLIED DISEASES

By Geo. H. Glover

Colorado Agricultural College
Colorado Experiment Station
Fort Collins

The Colorado Agricultural College
FORT COLLINS, COLORADO

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HOG CHOLERA AND ALLIED DISEASES

By Geo. H. Glover

The purpose of this bulletin is to meet a demand for practical information respecting hog cholera and allied diseases, their recognition, and first aid measures looking to their control.

A characteristic feature of hog cholera is its periodic appearance, and just now it is spreading rapidly in many of the states. The classical hog cholera as a conception of former days is no longer seen and we now have to deal with several mixed infections that either accompany cholera or follow closely in its wake. The losses from this disease are enormous, and this in face of well-established facts concerning its control by timely sanitary measures, quarantine and vaccination.

Delayed diagnosis, or recognition of the disease, is no doubt responsible, more than any other one factor, for the repeated outbreaks and heavy losses. **Hog cholera is the only common disease among hogs in this country that spreads rapidly and is highly fatal.** For this reason farmers and veterinarians should always go on the assumption that every outbreak of disease among hogs that is spreading rapidly and has a deadly aspect, is cholera, and should immediately proceed on that assumption without waiting for a definite diagnosis based on characteristic symptoms and postmortem findings.

Specific Cause

The specific cause of hog cholera is a virus that will pass thru dense filters. This virus is the immediate or exciting cause of cholera. Indirect or predisposing causes are such things as neglect, exposure, parasites, unbalanced food ration and insanitary conditions. In other words, such things increase their susceptibility to cholera as it does to all other diseases. We cannot grow a crop of potatoes without planting potato seed, and no more can there be cholera in hogs without the implanting of the specific germs or virus in the body of the animal. However, the fact remains that no matter how thrifty hogs may be they are nevertheless highly susceptible to cholera.

Cholera Dissemination

The most common method of introducing hog cholera into a neighborhood is thru the importation of breeding or stock hogs that carry the infection. For all practical purposes it must be assumed that all stock cars and stockyards are infected. There

is no other way in which hogs are so sure to contract cholera as by actual contact.

The next most common means of conveying the infection is running water, like rivers and irrigating ditches. This applies of course in a special way to conditions in Colorado. Hogs that have access to the upper reaches of an irrigation ditch endanger hogs down stream for many miles.

No doubt new centers of infection result from garbage that contains pork rinds from infected hogs, and entrails from chickens shipped from cholera infested farms.

Presumably cholera is also spread by birds, especially pigeons and magpies, by the wheels of vehicles, on the feet of itinerant hog buyers and inquisitive neighbors, and by animals allowed to run at large.

Lastly, and perhaps the most serious aspect of hog cholera control, is the dissemination of the disease by the careless use of virus in vaccination.

Symptoms

The length of time between exposure and the appearance of the first symptoms is on the average 6 to 10 days. The symptoms will vary according to the type of the disease. Fever always goes in advance of outstanding symptoms and one should always be suspicious when hogs "go off feed" as indicated by trailing the herd when coming to the feed trough or remaining buried in their litter. The first symptoms usually noticed are loss of appetite and chills. Soon they manifest marked weakness in their hind quarters, the eyes become inflamed and there is gumming of the eyelids. First there is constipation followed in a day or two by diarrhea. Breathing is labored and usually there is a persistent cough. Reddening of the skin on the belly and inside of the thighs is usually seen. Unfortunately a positive diagnosis cannot always be made on living animals, and for this reason much valuable time may be lost. In peracute cholera, most often seen at the beginning of an outbreak, they sometimes die within a few hours without having had time to develop the characteristic symptoms or lesions. In chronic hog cholera, usually following the acute, there is a persistent cough, poor appetite, emaciation, diarrhea and indications of pneumonia.

Mixed Infections

Pure hog cholera probably never exists. What we know as hog cholera these days is a disease process caused by mixed infection. If it were pure cholera the losses would not be so great.

The disease in itself is not so very malignant but becomes exceedingly fatal as a result of secondary inflammatory processes in the intestines and lungs.

The intestinal complications seem to invariably follow in the wake of hog cholera. The microorganism responsible for this condition (Salmonella suipestifer) was at one time thought to be the specific cause of hog cholera, but it was later repeatedly demonstrated that the disease could be produced artificially by the filtrate of cholera blood. In other words, after the blood had been forced thru dense filters and the S. suipestifer with all other bacteria held back, the filtrate still contained an ultra visible virus that, when inoculated into hogs, would cause cholera.

The suipestifer disease may appear independent of cholera, in which case it is known as swine dysentery, pig typhoid, paratyphoid, necrotic enteritis, etc. This will be treated later in the discussion on necrotic enteritis.

The secondary inflammatory processes in cholera involving the lungs is usually a manifestation of swine plague which is the same thing as hemorrhagic septicemia. This pneumonia complication is commonly seen in cholera, save in the peracute type (septicemic) when the animal dies before pneumonia has had time to develop. The almost constant appearance of these secondary infections in cholera makes it seem probable that both the paratyphoid and swine plague organisms are normally present in the intestinal tract of hogs. They ordinarily do not cause disease but may do so when the resistance of the animal is lowered by an attack of cholera, by exposure, improper feed, parasites, cold or various infections. It seems that hog cholera lowers the resistance in a particular or unusual way that renders them especially susceptible to these secondary infections.

Control Measures

Prevention of hog cholera is the principal thing and many farmers have maintained healthy herds even when adjacent to cholera-infested farms. When cholera is threatening, watch your hogs, maintain a strict quarantine, keep people and animals away from them, and hogs brought to the farm should be kept in isolated quarters for at least 3 weeks. However, when cholera is threatening the security of your herd to this extent, vaccination should not be delayed.

When cholera is suspected in the herd, immediate action is imperative. Aside from the curative value of large doses of serum, under certain conditions, there is no known cure for hog cholera. Time is the essence of the contract in this instance. If

the herd is vaccinated on the day, or the day following the first appearance of the disease, most of them can be saved. If treatment is delayed a week or more there is the question as to whether vaccination is worth while since most of them may be expected to die regardless of treatment.

Naturally the first thing to do is to call a veterinarian and demand immediate action. If the diagnosis of hog cholera is affirmed, the office of State Veterinarian at Denver should be notified. Should you be in a remote district where veterinary service is not immediately available, communicate with the state veterinarian by telephone or telegraph. Failing to reach him get in touch with the United States Bureau of Animal Industry, Federal Building, Denver. The veterinarians at the agricultural college do not go into the field to vaccinate hogs but always stand ready to assist in every other possible way.

Hogs from a cholera-infested herd should not be shipped to market. By the time they reach their destination some of them will be dead, others sick, and the salvage will be less than it would be if they were kept on the farm and immediately vaccinated. Hog cholera can never be controlled until this practice is legally prohibited. The highways over which the diseased hogs are transported are very sure to become contaminated by the excreta containing the cholera-producing germs.

Hogs that are not thrifty should not be vaccinated; the consequences of such a mistake are very sure to be unsatisfactory. In the vaccination of healthy herds, in cholera-infested districts, the double treatment (serum and virus) is recommended. **The important thing in this connection is the amount of serum used.**

Economy in serum too often proves to be the height of extravagance. Larger doses of both serum and virus are given than formerly.

In the vaccination of infected herds the procedure is different. The temperature of each hog is taken. Those that show a temperature around 104°F. should be given the serum. The assumption is that they will get sufficient virus by contact with sick animals to insure them a lasting immunity. Some contend that it is better to give the double treatment in this class of hogs in order to insure a uniform and lasting immunity. Hogs that have a temperature of 106-8°F. had better be destroyed, since there is no chance for their recovery, and they simply increase the menace of the herd. Those hogs that show only a slight fever should be given double doses of the serum alone with the hope of saving at least some of them.

Following vaccination, and the disposal of hopelessly infected hogs, attention should be directed to cleaning and disinfecting the premises. **It is far better to burn hogs that are slaughtered for cholera than to bury them.** The carcasses are quickly consumed by a fairly hot flame. If they are buried they should be placed deep with several buckets of quicklime covering them. All litter and waste from the pens should be burned and if possible the ground in the hog lots should be plowed. To make the job of disinfection more thoro, the woodwork of the pens and hog houses might be whitewashed and quicklime used freely in the pens and yards. A 3 percent solution of compound cresol is a very reliable disinfectant for general use. The hogs that remain and have been vaccinated should then be provided with dry, clean and comfortable quarters. In well-known cholera districts vaccination of all pigs at weaning time is a cheap insurance if practiced consistently.

Necrotic Enteritis

Infectious necrotic enteritis probably causes a greater loss in the aggregate than does hog cholera.

Pig typhoid, bacillary hog cholera, swine typhus, intestinal necrobacillosis, swine dysentery, paratyphoid and necrotic enteritis are terms that probably relate to one and the same disease. This disease which appears both associated with hog cholera and independently must not be confused with coccidiosis which is sometimes mentioned as infectious enteritis of swine.

Pigs weighing from 30 to 50 pounds are most susceptible, and the quality and nature of the food seem to have very little influence upon the prevalence of the disease. The heavy losses that occasionally follow vaccination for cholera are largely due to necrotic enteritis.

It seems to have been demonstrated beyond a reasonable doubt that the specific microorganism, S. suipestifer, is the causative factor in infectious necrotic enteritis of swine. It occurs mostly as either an acute or chronic affection.

In the acute form (septicemia) there is a high temperature, inappetence, arched back, "blue belly" and diarrhea. This type is very fatal. In the chronic type, which is most common, the animals first appear dull, are less active, and have a diminished appetite, altho this may not be noticed by the caretaker. Digestive disorders soon appear, manifested by a persistent diarrhea. They appear unthrifty, stand around with their heads down, the hind quarters weave from side to side from weakness, and they finally die from emaciation and exhaustion, or a few may, after hanging on a long time, make a questionable recovery.

Control Measures.—All curative measures have been very discouraging. The acute cases are especially hopeless because they do not live long enough to respond to treatment. In chronic cases, those that appear hopelessly diseased should be destroyed. The diet should be regulated and concentrated food withheld. A liquid or slop diet of ground oats, barley or shorts, is preferable. This had better be made alkaline by adding caustic soda or lye in the strength of 1 pound to 20 gallons. In this case, as in all cases of infections among animals, the sick ones should not be removed from the well ones, but on the contrary, the well ones should be taken away from the sick ones and placed in new, clean quarters. In the summer time it is best to place them in an alfalfa pasture where there is shade and an abundance of fresh water.

This disease is not highly infectious like hog cholera and can usually be controlled by the comparatively simple methods suggested. The virus appears to die quickly when not replenished by the presence of diseased animals. Never vaccinate for cholera when there is any indication of necrotic enteritis in the herd.

Swine Plague

Swine plague and hemorrhagic septicemia of swine are synonymous terms. Swine plague occurs both as an independent disease, and in association with other disease, especially hog cholera. Unlike cholera it does not spread rapidly from hog to hog or from farm to farm. It is caused by a specific germ, Pasteurella suisepticus, (Bacillus suisepticus) which is a variant in a group of organisms that cause chicken cholera, snuffles in rabbits, tularemia in man, bubonic plague in man, hemorrhagic septicemia in cattle, horses and other animals. As an independent disease in hogs it is not of the highest importance, but as a secondary infection in hog cholera, it contributes a disease process of the lungs which renders hog cholera the most fatal of all diseases of swine. The spread of pure swine plague is slow and in this respect is not to be compared with cholera. Swine plague bacilli are commonly found in the intestinal tract of healthy hogs. It is now believed that these normally harmless organisms may become pathogenic under certain conditions of lowered resistance. Possibly the presence of hog-cholera infection lowers the resistance in a particular and direct way. Again we are confronted with the proposition that an ample food ration, well balanced, combined with good care, is the best kind of insurance against disease.

In the San Luis Valley it has been noted that many cases of swine plague follow exposure during cold, rainy weather in the fall.

Medicinal treatment, according to our present knowledge, is without effect, save that highly potent serum will favorably influence the disease. Prevention is of vastly more importance than treatment. Animals not showing indications of the disease should be immediately removed to clean quarters. The stable, pens and feeding trough should be disinfected. These measures seem justifiable even tho the danger of infection is not great.

Biologics when appropriately used may be useful as a control measure. Among these, aside from the specific serum, may be mentioned the mixed infection bacterin, and hemorrhagic septicemia aggressin. The use of biologics should always be left to the judgment of the veterinarian.

A distinct form of chronic pneumonia affecting very young pigs has sometimes been spoken of as a form of chronic swine plague. This disease has also been called enzootic pneumonia of pigs, pig disease, pig cough and cement disease. There is very little support for the view that the acute swine plague has changed into a chronic catarrhal pneumonia. The specific cause of pig pneumonia has yet to be determined. Frequently in a litter one pig after another, only a few days old, will begin to cough with a thumping respiration, and finally die. The incidence of this disease appears to be the association of untoward conditions such as cold and damp pens, unsuitable feeding of the mother, lack of sunshine and possibly inbreeding.

Hog "Flu"

Hog flu, or perhaps more appropriately, infectious bronchitis of swine, considered from a purely economic standpoint, does not belong in the same category with hog cholera and infectious necrotic enteritis. It derived its name "hog flu" by reason of the fact that it was first recognized in the fall of 1918 when human influenza was sweeping the country and the symptoms were so much alike as to attract attention.

The onset is sudden and the symptoms are severe. In 1 or 2 days the entire herd may be affected. The most characteristic symptoms are loss of appetite and cough. They have high fever and difficult respiration. They are usually sick about 1 week and then make rapid and uneventful recovery. They lose considerable weight and this is really the most serious aspect of the disease.

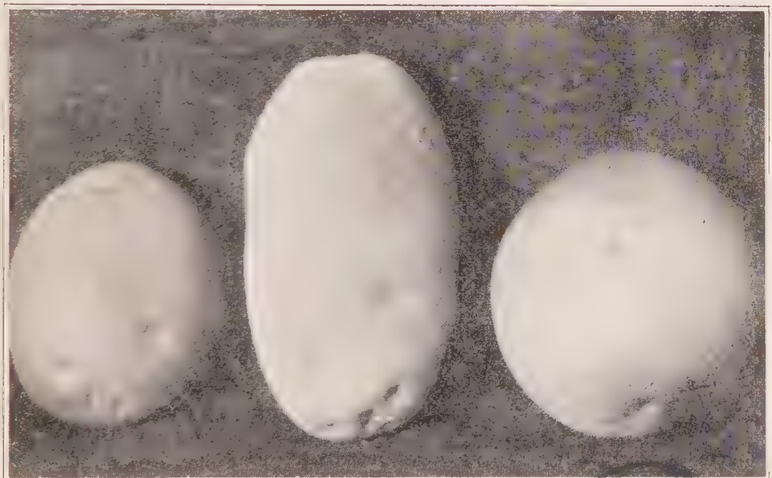
In some instances the disease is complicated with pneumonia and a fatal termination may be expected. The total loss rarely exceeds 1 to 3 percent.

There appears to be no immunity acquired from having the disease, which precludes the possibility of protecting herds by vaccination. A specific treatment has not been found, and no treatment seems to be indicated, further than providing dry, comfortable quarters and reducing the ration.

Bulletin 359 February, 1930

IDEAL TYPES FOR COLORADO STANDARD POTATO VARIETIES

By C. H. Metzger



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IDEAL TYPES FOR COLORADO STANDARD POTATO VARIETIES

By C. H. Metzger

The present-day potato market is not the same as 30 years ago or even 5 years ago. The consuming public has learned that a potato is not just a potato but that there is a marked difference in quality between different lots. Consumers have changed their methods of living, larger numbers living in apartment houses, and there is more hurry and less patience with anything that requires an abnormal amount of time. This present-day market demands "QUALITY."

Production Tendencies.—Certain changes have taken place in the production of potatoes, keeping pace with the changing market demands. Variety standardization has eliminated inferior varieties and reduced the number of varieties of commercial importance in the state to eight. The producer who made a practice of growing all the varieties he could find has practically disappeared and all progressive growers are now specializing on one or two varieties. This standardization program has not only reached the individual grower but has also affected the different producing sections of the state, each section specializing on two or three of the standard varieties. With these things accomplished, attention is now being centered on the individual varieties and all efforts concentrated on the improvement of QUALITY and YIELD and on lowering the cost of production. An active production campaign is being carried on in the state, the slogan of which is "More U. S. No. 1 Potatoes per Acre." This campaign is being furthered thru the medium of county potato-king contests, the state 600-bushel club and potato shows. Better seed, seed treatment, larger seed piece, more seed per acre, and crop rotation are all playing their part in producing higher yields of better quality. A high-quality product demands an attractive package, so even-weight, branded bags of all sizes, 120, 100, 25 and 15 pounds, are being used and crates of 50-pound capacity as well as 15-pound cartons are taking care of extra-quality even-sized lots.

ACKNOWLEDGMENTS.—The specimens from which the cuts are made were obtained thru the courtesy of the exhibitors and management of the San Luis Valley Seed Show at Alamosa and the State Seed Show at Colorado Springs.

The terms used and some suggestions were obtained from the Proceedings of the Potato Association of America and Professor William Stuart's book, "The Potato."

The photographs, with the exception of the cover plate, and Figures 9 and 12, were made by Grant C. Eddy, college photographer.

Quality Defined.—The potato show or potato exhibit is based on this idea of QUALITY. The term "quality," based on the interpretation of the U. S. grades or on a scorecard, includes several subdivisions or factors which determine the quality of a given lot or sample of potatoes. These include trueness to TYPE, freedom from disease, freedom from mechanical or insect injury, uniformity, most desirable size, general appearance and from the market standpoint, the amount of waste in preparing for the table. All these factors are self-explanatory and generally understood by those interested in potatoes from the market or show standpoint except varietal type.

Type Defined.—There has been some confusion and a lack of standardized ideas over the state as to what constitutes trueness to type in a given variety. It is the purpose, then, of the following discussion, to present the ideal type of each of the leading commercial varieties of potatoes for the benefit of growers who select seed or show samples and students of potatoes who are interested in judging.

The first question which naturally arises is: What is meant by varietal type? Varietal type refers to the shape or form of the tuber, to the color and texture of the skin and to the location, number and depth of eyes. All of these things are more or less variable and depend upon certain inherent and environmental factors. The variety is, of course, the greatest determining factor of type and type is fairly constant within the variety but is influenced, modified and changed by a number of different factors.

Effect of Disease.—One of the most important of these factors is disease, particularly the degeneration or virus diseases, which cause what is known as "running out." Spindle tuber probably has a more pronounced effect on type than any other disease. Tubers from spindle-tuber-infected hills are generally more or less lengthened along the longitudinal axis, spindle shaped and cylindrical, the eyes are more numerous and smaller and the eyebrows are more pronounced than in normal tubers. A change in color may also occur as a result of spindle-tuber infection. This has been observed particularly in the Triumph and Peachblow varieties, infected tubers being lighter in color than normal tubers or blotched light and dark.

A comparatively new disease known as giant hill also has a marked influence on tuber shape. "Tubers are generally elongated and thickened, pointed at one or both ends, frequently constricted at some point on the longer axis and provided with numerous eyes which are either flush with the surface or some-

what protuberant." Giant hill is closely related to spindle tuber or may merely be a phase of it.

Mosaic and leaf-roll-infected plants often produce abnormally smooth, perfectly formed tubers under our conditions so growers should beware of these and select eyes normal for the variety and not extremely shallow-eyed specimens. The parasitic diseases may also, at times, exert an influence on the type of the tubers. A pointed or wedge-shaped stem end is sometimes associated with fusarium. Rhizoctonia may cause knobbyness or misshapen tubers because of crowding in the hill.

Effect of Environmental Factors.—Various environmental factors may also affect the type of the tubers. The first of these is soil. In order that a tuber may assume its normal shape it must be grown in a mellow, well-prepared soil, free from rocks and clods, well drained and containing abundant fertility. Well-shaped tubers cannot be grown on a soil which is tight, not plowed deeply enough, not pulverized finely enough or is not fertile enough. Soil may not only influence the shape of the tuber but may also affect the texture of the skin. On some soils, russeted varieties have a very light netting and in other cases smooth-skinned varieties are produced with a roughened lightly netted skin. In poorly drained soils poor-shaped tubers with large russeted dots on the skin are produced. Much better-shaped tubers are produced on light than very heavy soils.

A second environmental factor is moisture. The plants must constantly have enough moisture to keep them in vigorous growing condition. An irregular moisture supply causes rough, irregular and knobby tubers. An excess of moisture encourages disease and causes some varities to growth crack.

The third environmental factor is temperature. The potato is a cool-season plant and develops perfectly only at relatively low temperatures. In Nebraska it was found that high soil temperatures had the same effect on tuber shape as the spindle-tuber disease.

Selection has considerable influence on type and on the elimination of diseases.

Even tho tubers have been produced under the optimum of all the above-mentioned conditions, considerable variation is still found in the length, width, thickness, smoothness and position and depth of the eyes in individual tubers. For this reason it has been necessary to arbitrarily select the ideal type. Symmetry and the proper degree of smoothness have also had a very important bearing in the selection of the ideal type.

Irish Cobbler

The Irish Cobbler is an early variety generally grown thruout North America. In Colorado it is grown commercially, as an early crop, in the Fruita district in Mesa County, the Fort Morgan-Brush district in Morgan county and to some extent in the Greeley district in Weld County. Certified seed of this variety

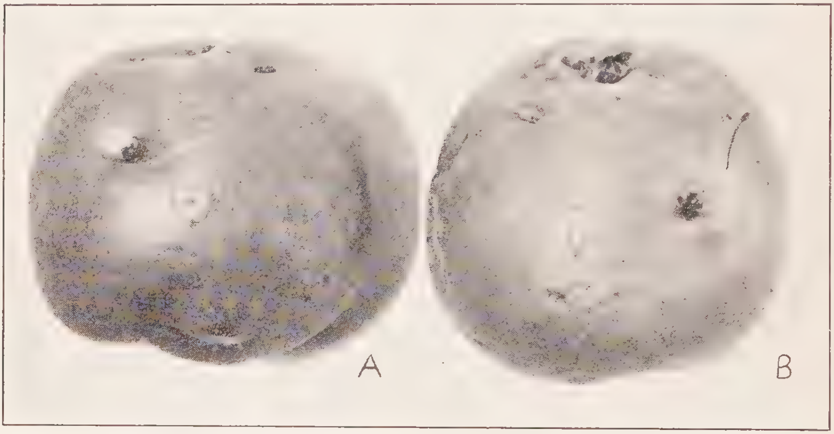

Figure 1.—Ideal types of Irish Cobbler.

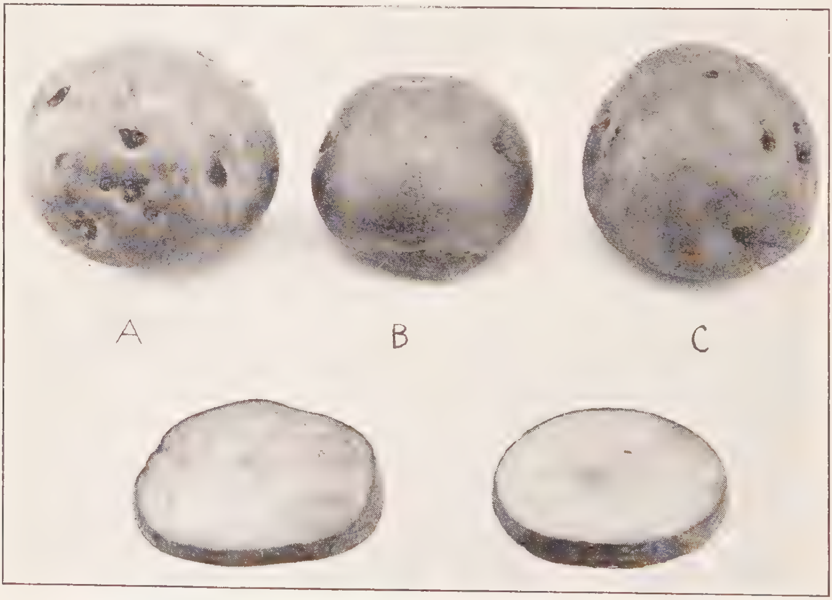

Figure 2.—Apical, basal side view and cross-sections of excellent Irish Cobblers.

is produced, without irrigation, in several other counties at elevations ranging from 6000 to 9300 feet.

The tubers tend to be more or less irregular in shape which makes it somewhat difficult to get a perfectly uniform sample.

Description.—Shape—Roundish
Apical end rounded
Basal end rounded, distinctly depressed, often notched and shouldered.
Skin—On some soils the skin is light, creamy-white and perfectly smooth. On other soils it is creamy yellow and lightly netted.
Eyes—Medium in number, mostly at the apical (bud) end, varying from shallow to rather deep, particularly in the bud-eye cluster which is set slightly on the side. (Fig. 1B)

The tubers should be short, as thick as possible, and round in outline. This ideal is illustrated in Figures 1 and 2. The bud-eye cluster should be slightly toward the top as shown in tuber B, Figure 1. The eyes in this tuber, however, are too shallow. More desirable eyes are shown in tuber A, Figure 1, and A, Figure 2. Note the thickness of C and the cross-sections in Figure 2.

Common faults found in Cobblers are lack of thickness, too much length, and too deep or too shallow eyes.

Measurements of a perfect type, 6-ounce Irish Cobbler:

Length	$2\frac{3}{4}$ inches
Width	$2\frac{7}{8}$ inches
Thickness	$2\frac{3}{4}$ inches
Longitudinal circumference	$8\frac{1}{2}$ inches
Transverse circumference	9 inches

Bliss Triumph

This is also an early variety grown commercially for the very early crop in the southern states. It is also grown for seed in a number of northern states. In Colorado it is used for the early crop in the Greeley district, San Luis Valley, Montrose section and more recently around Rifle. It is also the most successful variety in most of the non-irrigated sections. The heaviest production of certified seed in the state, during the past 3 years, has been of this variety. The certified seed has been grown in dryland sections in the northeastern and northwestern corners of the state and in non-irrigated sections of high altitude. It is a very desirable variety for the home garden.

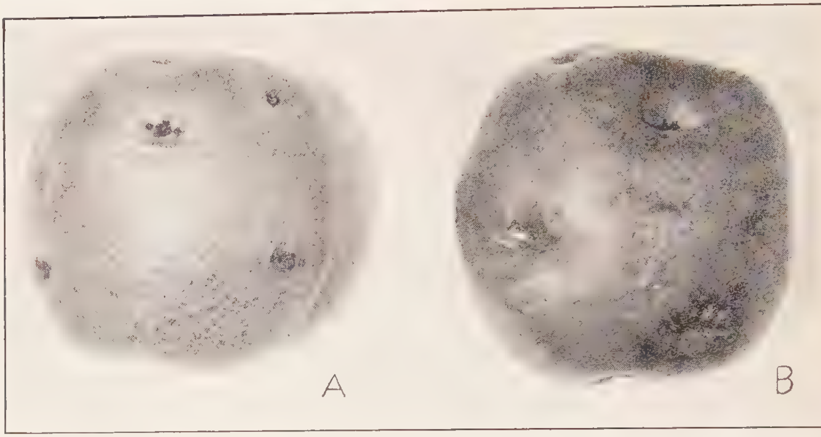

Figure 3.—Ideal types of Bliss Triumphs.

Description.—Shape—Cubical, rounded,
Apical end blunt
Basal end blunt, depressed.
Skin—On some soils, smooth and red or magenta colored; on other soils, lightly netted and somewhat paler in color.
Eyes—Medium in number, rather shallow; bud-eye cluster generally more or less depressed and set squarely on the end.

The tubers should be as near a cube as it is possible to get them, short, thick and blunt on both ends. Figures 3 and 4 illustrate the ideal type. In Figure 3, note the shallower eyes and netted skin of A, caused by a sandy alkaline soil, and the perfect type of B. Note the thickness of the tubers in Figure 4.

Shallow tubers, pointed ends, too much length and displacement of the bud-eye cluster from the center of the apical end are common faults found in Triumphs.

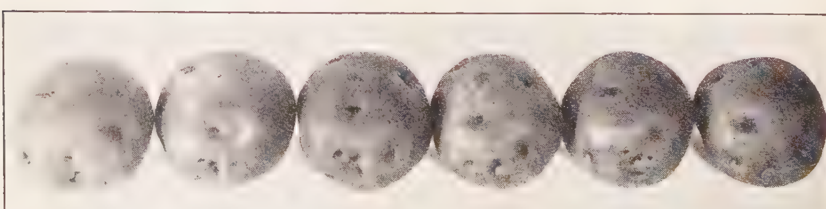

Figure 4.—Ideal types of Bliss Triumph, showing thickness and position of bud-eye cluster.

Measurements of a perfect type, 5-ounce Bliss Triumph:

Length	$2\frac{3}{8}$ inches
Width	$2\frac{1}{2}$ inches
Thickness	$2\frac{1}{4}$ inches
Longitudinal circumference	7 11-16 inches
Transverse circumference	$7\frac{7}{8}$ inches

Early Ohio

This is also an early variety, popular in home gardens and grown commercially in the Red River Valley of Minnesota. In Colorado, both the market and certified seed crops are grown in El Paso County. It is also grown in gardens in other parts of the state.

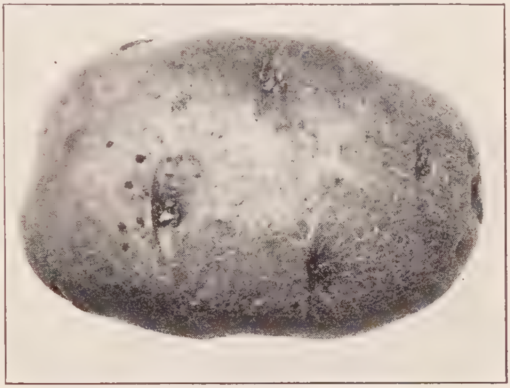

Figure 5.—Ideal type of Early Ohio.

Description.—Shape—Round, oblong to cylindrical
Apical end blunt
Basal end blunt and only slightly depressed

Skin—Flesh or light pink slightly deeper around the eyes and at the apical end. Either slightly netted or smooth, depending on soil. Some strains are paler colored than others and may be nearly white except for eyes which are pink. Surface dotted with small corky, raised dots (lenticles) more conspicuous when grown on some soils.

Eyes—Numerous, rather shallow but strong, bud-eye cluster square on the end or very slightly to the top, not much depressed, nearly flush with the surface.

Figure 6.—Apical, basal side and cross-sections of Early Ohio tubers.

Thickness is also desired in this variety. Note tuber C and the cross-sections in Figure 6. The tubers should also be quite short as in Figure 5 and rounded but full on the ends. Figure 5 may be criticised for being a little rough at the basal (stem) end. The apical end however, is good compared to A and B in Figure 6. Note the tubers are slightly pointed which is undesirable.

Common faults in Ohios are pointed ends, flat tubers, too much length and too deep eyes.

Measurements of a perfect type, 9-ounce Early Ohio:

Length	$3\frac{7}{8}$ inches
Width	2 7-16 inches
Thickness	2 3-16 inches
Longitudinal circumference	10 9-16 inches
Transverse circumference	$8\frac{1}{8}$ inches

Russet Burbank

The Russet Burbank is grown in a few western states, Washington, Idaho, Montana and Utah, where it is most generally known as the "Netted Gem." In Colorado it is grown both for market and for certified seed in the Carbondale district, the Eagle Valley and mostly on the heavier river-bottom soils in the San Luis Valley. It is late in maturing and is considered one of the highest quality varieties grown.

Figure 7.—Ideal types of Russet Burbank.

Description.—Shape—Cylindrical to oblong, rounded, inclined to be somewhat spindle shaped.

Apical end—runded but full

Basal end—rounded, full, but very slightly depressed. The depression is often almost entirely absent.

Skin—Heavy russeted or heavily netted. The degree of russeting depends on the soil and the altitude at which grown. Heavy netting is most desirable. The color is more pronouncedly influenced by soil color than any other variety. In very sandy soils the color is bright golden. Other heavier and variously colored soils transmit their color in a greater or lesser degree to the tubers. A few farms around Gypsum and Carbondale have brilliant red soils which adhere to the tubers producing the famous

"Red Soil Burbanks." Chocolate and black soils have a similar effect. In Idaho the volcanic ash soils give the tubers a grayish cast.

Eyes—Numerous, evenly distributed, shallow but indicating strength. Too shallow indicates weakness. The bud-eye cluster is shallow but not flush or protuding and is located slightly toward the top-side of the tuber.

Tuber B, Figure 7, shows an ideal type Russet Burbank, tuber A being slightly too spindle shaped. In Figure 8, tuber A is slightly pointed, B is a side view of a perfect tuber; note the thickness and perfect eyes in this specimen and the thickness in the cross-sections. The broader tubers are more apt to be a little flatter.

Common faults of this variety are: Pointed ends, too deep or too shallow eyes, not heavily netted and too much length.

Measurements of a perfect type, 9-ounce Russet Burbank:

Length	4¾	inches
Width	2⅜	inches
Thickness	1 15-16	inches
Longitudinal circumference	11⅜	inches
Transverse circumference	7 11-16	inches

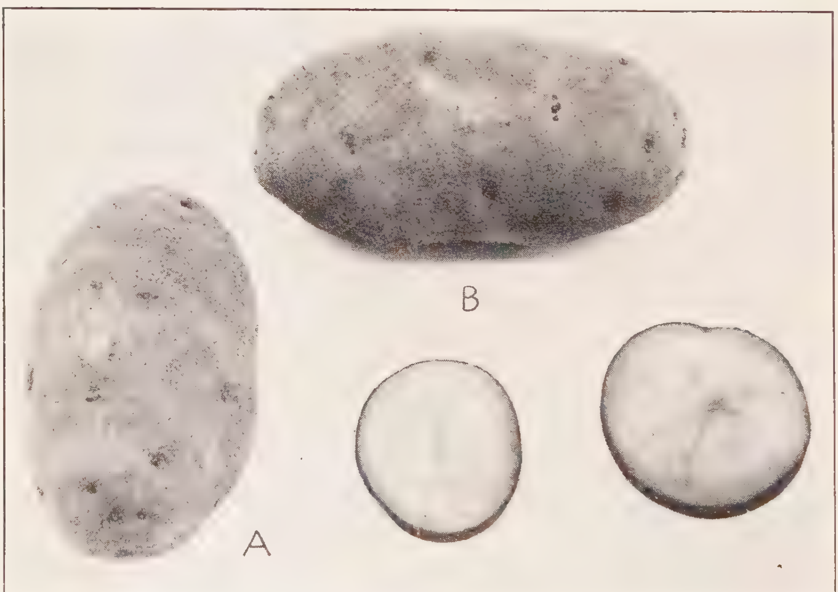

Figure 8.—Apical, side and cross-sections of excellent Russet Burbank tubers.

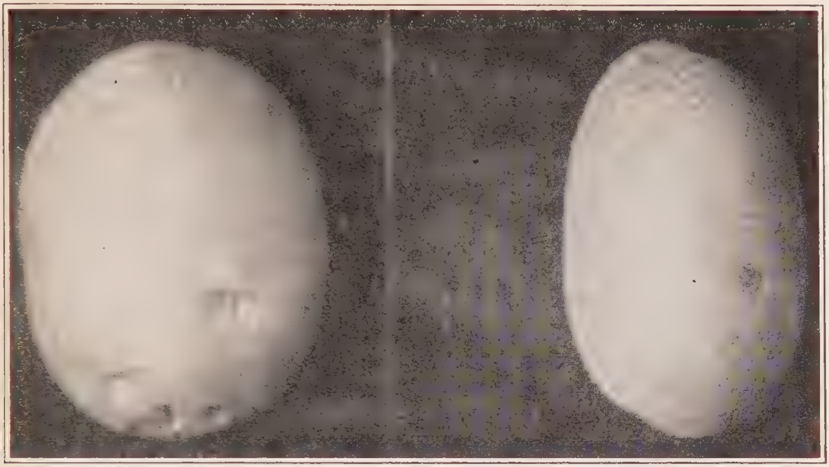

Figure 9.—Top and side view of the same Brown Beauty tuber.

Brown Beauty

This variety is the chief one grown in the San Luis Valley of Colorado, where it seems peculiarly adapted to the conditions. Attempts to grow it outside the valley have met mostly with failure except in a few cases during the last 2 or 3 years where certified seed was used. The variety sets very heavy, and consequently requires abundant moisture and fertility to make the tubers of marketable size. The American record was broken in 1929 by L. G. Schutte of Monte Vista, with 1145.17 bushels of Brown Beauties on a measured acre.

Description.—Shape—Oval rounded to slightly flattened. Apical end rounded but full, smooth Basal end rounded but full, only slightly depressed, very smooth.

Skin—Creamy yellow to buff, when first dug tinged with pink in eye depressions, which tends to fade out on exposure to light or after a period in storage. Glossy and smooth on some soils but generally dull and lightly netted or flaked.

Eyes—Medium in number, often shallow or fleet, preferably medium in depth with a long eyebrow. Bud-eye cluster medium deep and situated slightly toward the top side of the tuber.

Figure 10.—Apical, basal, side and cross-sections of good Brown Beauty specimens.

Note the thickness, depth of eyes and oval shape of the tuber in Figure 9. Even thicker tubers with deeper eyes have given excellent results but the symmetry in this type tuber is lost. Figure 10 shows extremely smooth, symmetrical tubers but still having a fair degree of thickness.

Common faults in Brown Beauties are extreme flatness, extreme smoothness, too much length and pointed ends.

There are also several off-types which occur in Brown Beauty stocks. Blue-blossomed individuals should be rogued from the field. Giant hills or "bastards" are also too common in some stocks. Two white-eyed types also occur. One is very smooth and round and generally small, as high as fifty of this type occurring in the same hill. The other is large and generally rough. The small round tubers occur on a spinach-leaf plant. The leaves are shorter and wider than normal; in other words heart-shaped instead of long, narrow and sharply pointed.

Bin selection of seed, as commonly practiced, will never rid stocks of these evils.

Measurements of a perfect type, 6-ounce Brown Beauty:

Length	3 15-16	inches
Width	2⅜	inches
Thickness	1 9-16	inches
Longitudinal circumference	8¾	inches
Transverse circumference	7¼	inches

Peachblow

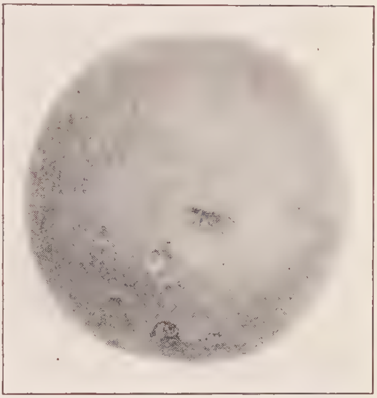

Figure 11.—Excellent type of the perfect Peachblow.

The full and proper name for this variety is "Perfect Peachblow," sometimes erroneously called Red McClure, and should not be confused with other numbers of this group grown in southern and eastern states. Like the Brown Beauty it is grown on a commercial scale, exclusively in Colorado. It ranks next to the Brown Beauty in the San Luis Valley but is becoming more popular and threatens to surpass the Brown Beauty. It is also grown to a more limited extent in the higher mountain sections particularly around Carbondale.

Description.—Shape—Roundish, rounded almost spherical
Apical end rounded
Basal end rounded with a very shallow depression.

Skin—Red or magenta around eyes grading to light pink on a yellow background. On some soils, and in some strains, the yellow and light pink are not as perceptible as on others. On some soils the skin is smooth and shiny and on others, smooth and dull, but it is generally lightly netted or heavily flaked.

Eyes—Few in number, four outside the bud-eye cluster in perfect specimens. Shallow, located mostly at apical end. Bud-eye cluster, medium in depth.

Figure 11 shows the round outline of the ideal type. Note the light netting of the skin. The bud-eye cluster is a little shallow in this specimen and it does not show the strength shown by the specimen in Figure 12. A side view and top view of the same tuber are shown in Figure 12. Note the thickness of this individual and how this thickness is carried thruout the length of the tuber from apical end to basal end. The eyes are

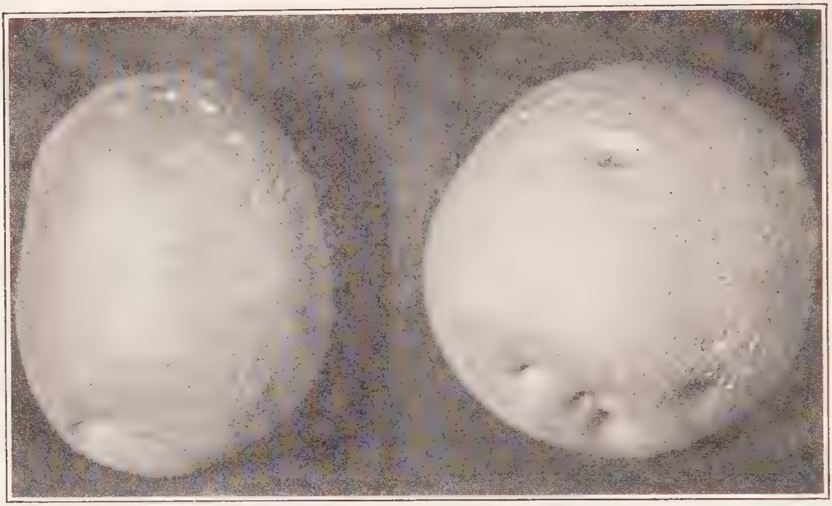

Figure 12.—Side and top view of the same perfect Peachblow tuber.

stronger and more desirable from a seed standpoint than those in Figure 11. Also, note the flaking of the skin contrasted with the netting of the specimen in Figure 11. The distortion of the top view is caused by the angle from which the photo is taken. A better view of the same individual is shown on the cover of this publication.

Common faults of Peachblows are flatness, too much length, pointed ends, oval shape instead of round and splashes of color, known by growers as "zebras," instead of the even blending of colors.

The same off-types occur as are found in the Brown Beauty. The high percentage of virus or degeneration diseases has resulted from continued bin selection. Giant hill, mosaic, spindle tuber and leaf-roll are much too common in both these varieties. The Peachblow is also the most susceptible to blackleg.

Measurements of a perfect type, 6-ounce Peachblow:

Length	2⅝ inches
Width	2⅝ inches
Thickness	2⅛ inches
Longitudinal circumference	8¼ inches
Transverse circumference	8¼ inches

Rural

Members of the Rural group of potatoes probably lead all others in commercial production in the United States. A large part of the crop in New York, Michigan, Wisconsin, Minnesota,

Pennsylvania, Ohio and Iowa consists of varieties in this group. In Colorado two members of the group are grown: Rural New Yorker No. 2, and Russet Rural. These are the major varieties in the Greeley district and the smooth type is the most important in the Bostwick Park section of Montrose County. They are the latest maturing varieties grown in the state.

Description.—Shape—Short, oblong, somewhat flattened.
Apical end blunt.
Basal end blunt, slightly notched.

Skin—Creamy white, sometimes having a buff sheen, glossy or sometimes lightly netted in the Rural New Yorker No. 2. Dark russet in the Russet Rural.

Eyes—Medium in number, shallow. Bud-eye cluster strong and slightly depressed, situated very nearly on the end slightly toward the top side.

Tuber A in Figure 13 is an excellent specimen but is a trifle too long. It is of the type commonly picked for show purposes but a shorter specimen is more desirable. Tuber B is of a rounder type and has the desired shortness but blockier ends are a little more desirable. Figure 14 shows three views (side, apical end, basal end) and cross-sections of the same perfect individual.

Show samples of this variety have had fewer faults than the others: The most common fault being too much length. In the

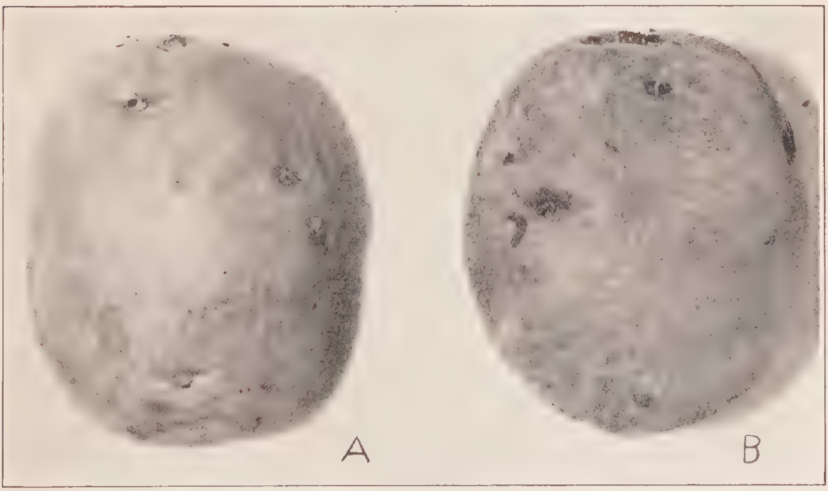

Figure 13.—Two good specimens of the Rural New Yorker No. 2.

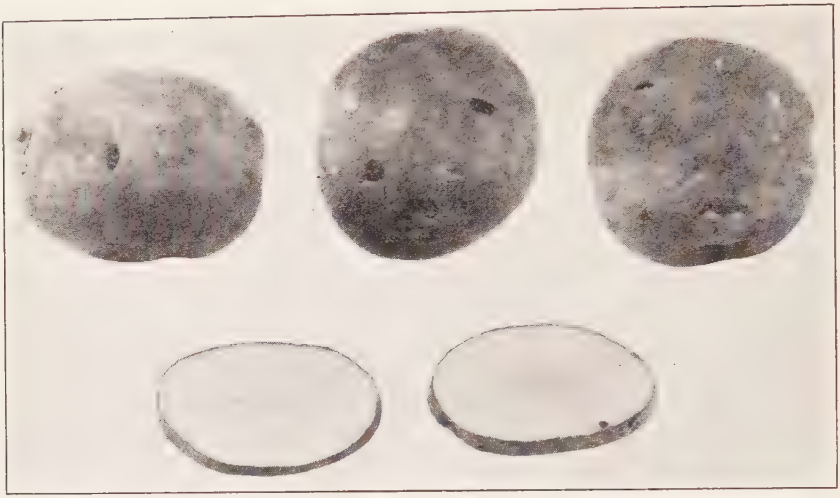

Figure 14.—Side, apical end and basal end of the same Rural New Yorker No. 2 tuber.

field, the most common defect is pointed ends and deep eyes resulting from spindle-tuber infection.

The tubers of this variety are sometimes confused with those of the Brown Beauty. The Brown Beauty has a faint pink coloration around the eye while the Rural has no color around the eye, but has purple leaf scales and tips on the sprouts. This color is not generally evident, however, until late in the storage period when sprouting starts.

Measurements of a perfect type, 9-ounce Rural:

Length	3¾	inches
Width	3 1-16	inches
Thickness	1⅞	inches
Longitudinal circumference	9 15-16	inches
Transverse circumference	8⅝	inches

Peoples Russet

This is a medium late-maturing variety belonging to the Pearl group. It is grown in a few localities on a limited scale, chiefly on heavy river-bottom soils in Montrose and Delta counties and around Rifle in Garfield County. The Peerless or Pearl, identical with Peoples Russet except that it has a smooth skin, was the pioneer variety in practically all of our commercial producing sections, but it is almost impossible to find a commercial field of this variety at the present time. In the Greeley section it has been replaced by the Rural and in the San Luis Valley by

the Brown Beauty and Peachblow. The Blue Victor, also identical except that it has a blue skin sometimes splashed with white, is still grown in a few isolated sections, but is unmarketable and is used only for home consumption and local demand. Mosaic has been the primary cause for the downfall of this group.

Description.—Shape—Short, heart-shaped, flattened.
Apical end rounded
Basal end blunt, depressed in Peoples, more or less deeply notched and shouldered in Pearl and Blue Victor.

Skin—Dark russet brown, netted. If dug before mature the brown pigmentation in the skin is present and the netting is absent. Occasionally white sploches occur. When one of these occurs over an eye, that eye gives rise to white tubers. White tubers and russet tubers sometimes occur in the same hill. The Pearl is dull white. When freshly dug it has a faint pink tinge in the eye depressions, fainter than in Brown Beauty, which also tends to fade as in Brown Beauty. The skin is sometimes lightly netted or flaked. The Blue

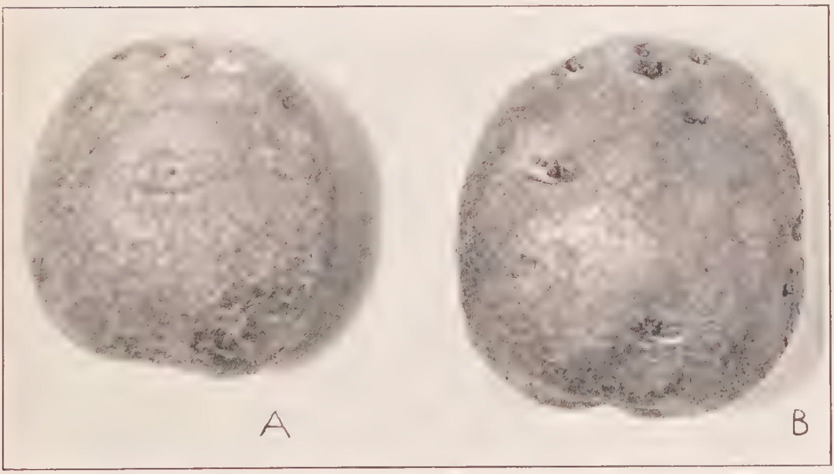

Figure 15.—A. Good type Peoples Russet. B. Good type Peerless or Pearl.

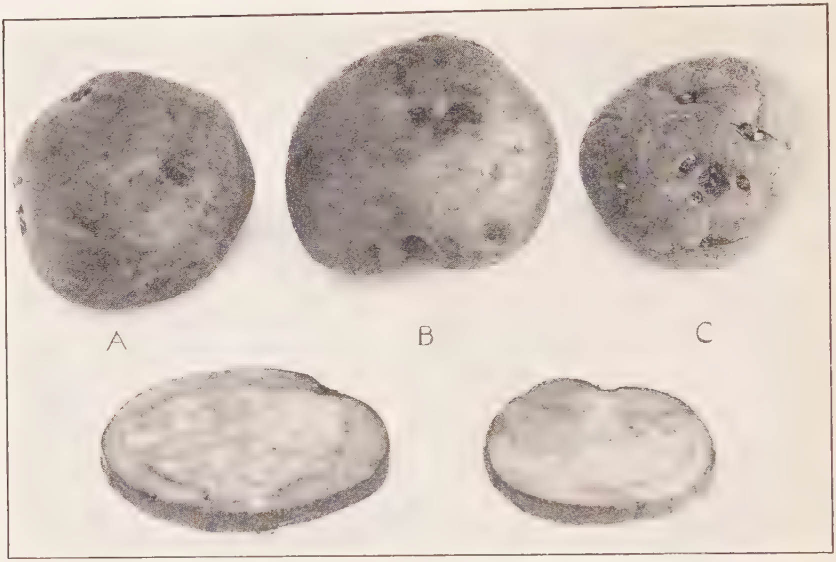

Figure 16.—Different views and cross-sections of the Pearl group.

Victor, as the name implies, has a deep blue color which is confined to the skin and does not extend into the flesh.

Eyes—Medium in number, shallow. The bud-eye cluster is quite shallow but should show strength. It is placed almost squarely on the end slightly toward the top.

The ideal type Peoples Russet is shown in Tuber A, Figure 15. Tuber B is an excellent type Pearl. Note the difference in the netting. The Pearl is sometimes flaked instead of netted. A and B in Figure 16 show the apical and basal ends of an excellent type Blue Victor. C is the apical end of an excellent Peoples Russet. Notice the strong sprouts. D is a cross-section of a Blue Victor and E is a cross-section of a Peoples Russet.

Common faults of the Peoples Russet are: Extreme length, oblong shape instead of short heart shape, deep eyes with heavy eyebrows and pointed ends.

Measurement of a perfect type, 8-ounce Peoples Russet:

Length	3 3-16 inches
Width	3 1-16 inches

Thickness	2⅛	inches
Longitudinal circumference	9¼	inches
Transverse circumference	9	inches

It is not to be inferred from the foregoing discussion of type that it is a reliable index of the quality of seed or that it should serve as the sole basis for seed selection, as the best-type tubers often come from the lowest-yielding hills. This discussion is merely to serve as a guide in the selection of show samples and to establish an ideal toward which to work in a hill-selection program or tuber-unit seedplot program. These and other methods of potato improvement and maintenance are discussed in another publication by this station.

Picking the Show Sample

The best time to pick the show sample is when the crop is being dug. The digger should be followed and the good-type specimens picked up, always being careful in handling them that they do not become cut or bruised. The great tendency is not to pick enough from which to select a sample—1200 or 1500 pounds are none too many in this day of keen competition. These should be stored in boxes in a cool, dark place until such time as the sample can be picked out. They should then be laid out and matched, making the sample as nearly uniform in size and shape as possible. Always pick the number required by the show (40 or 32) and several alternates. The discarded ones may be very advantageously used in a tuber-unit seedplot the next season. The tubers of the sample should then be individually wrapped in paper, placed in a box and stored in a cool, dry, dark place until the show. The tubers must never be washed but may be cleaned and brightened with a small hand brush.

Judging

The judging of the samples is based on certain definite standards which are slightly different for market and seed classes. The placing of the samples is based on QUALITY and the quality of a sample is made up of several factors. It is extremely difficult to arbitrarily assign a certain weight to each of these factors even tho these weights determine the placings. A scorecard names these factors and assigns to each a certain definite weight which is a measure of their relative importance. An experienced judge seldom uses a scorecard as it is very diffi-

cult to make one which will fit all the conditions which may be met in actual practice. The following scorecards will give an idea of the points considered, and in general the relative importance of each. The size of tuber and number of tubers required are generally specifically stated in the premium list. Exhibitors should always make a careful study of this list and of the rules of the show.

SCORECARD FOR SEED CLASSES

1.	Freedom from disease	30
2.	Trueness to type	25
3.	Freedom from mechanical or insect injury	15
4.	Uniformity	10
5.	Finish	10
6.	Seed size (5 to 8 ounces)	10
		100

All these terms are self-explanatory and easily understood except finish, which may seem to be a repetition of numbers one and three. However, when properly interpreted, such is not the case. Some soils turn out tubers with a much better finish than others, which adds to the general appearance. Maturity also generally adds greatly to appearance. It is these points and not loss in general appearance caused by disease or injury which are included under this head.

SCORECARD FOR MARKET CLASSES

Amount of waste in preparing for the table (type, disease and injury are included)	50
General appearance	25
Uniformity	15
Market size (9 to 12 ounces)	10
	100

In this case general appearance includes not only maturity and finish but also disease injury and type as it is considered from the housewife's standpoint.

Disqualifications: There are only a few disqualifications in judging potatoes:

1. Washed tubers
2. A mixture of varieties in the sample

3. A sample in the wrong class as Peachblow in a Triumph class or Rural in a Brown Beauty class
4. Any number of tubers other than that stated in the premium list.

All other defects are duly considered and if bad enough may throw a sample out of the money, but do not disqualify it.

Remember that a large part of the marketing problem can be solved in the production phase. There is always a demand for an assured supply of a superior-quality product. Good quality and high yields prevent losses in those years when prices are low and assure greater profit in good price years.

Make "More U. S. No. 1 Potatoes per Acre" your goal.

Bulletin 360 March, 1930

PASTURES FOR SPRING AND FALL GRAZING

IN MOUNTAINS OF COLORADO

By HERBERT C. HANSON

Colorado Agricultural College
Colorado Experiment Station
Fort Collins

The Colorado Agricultural College

FORT COLLINS, COLORADO

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PASTURES FOR SPRING AND FALL GRAZING

IN MOUNTAINS OF COLORADO

By HERBERT C. HANSON

One of the chief difficulties facing many stockmen is that of providing grazing land between the time that livestock must be taken off the hay meadows and before it is permitted to enter the national forests. This period varies from 1 to about 3 months. Providing range for fall grazing is usually a less serious problem. The opening of the grazing season on the national forests varies in different parts of the state from about May 15 to about July 1 and the closing dates from about October 1 to November 1.

If pasture land could be provided for early spring grazing there would be less temptation to use the hay meadows so late that the meadows are injured and less spring feeding might be needed (Fig. 1). There would be less loss from poisonous plants and unsuitable feed because fewer head of stock would have to be turned out on the range before the forage plants had developed sufficiently. Stock

Fig. 1.—Pasture consisting chiefly of smooth brome grass and yellow sweet clover on Table Mountain Ranch, near Virginia Dale, 7,000 feet. Planted in spring of 1925, photograph taken July 19, 1928.

could be maintained in better condition at less expense and because of this there would be higher calf and lamb crops.

Experimental plantings have been conducted during the past three seasons in order to determine if early spring pasture could be developed that might also be used in the fall. Altho the investigations have not been completed, a number of important facts have been learned that help to answer this question. Additional plantings and observations over a longer period of time are necessary, however, before final recommendations can be made. On account of the importance of this problem, of supplying early spring grazing to fill in the gap, it was decided to make the facts that have been found available to all who could benefit from them and to make preliminary recommendations.

The establishment of a pasture for early spring grazing is dependent chiefly upon the location of the area, preparation of soil for planting, seeding methods, kinds of plants and later treatment. If some irrigation water is available, especially during the first season, the chances of success are much greater but in most cases only the natural soil moisture can be depended on.

Location of Pasture

As a rule it is not advisable to plow up areas that are covered with a good stand of palatable native plants such as western wheat grass or porcupine grasses (see Fig. 2). Cultivated fields that have been abandoned, areas supporting plants of little or no forage value as sagebrush or poisonous plants, and areas on which the grazing capacity has been much reduced by rodents or faulty range-management methods should be seeded first. The pasture should be located in more or less of a depression so that the moisture supply in the soil may be increased somewhat by run-off from surrounding slopes and so that some protection is afforded from the drying and erosive effects of the wind (Figs. 1, 2 and 7). The soil should be fairly deep. Seeding will usually not succeed on thin soils or on areas that dry out rapidly as hillsides. The danger of both water and wind erosion should always be seriously considered before plowing up the soil, even if the stand of vegetation is thin. Cultivating the soil may start erosion that might be difficult or impossible to stop later.

Preparation of Soil for Planting

One of the chief aims in preparing the soil for planting is to secure as firm a seedbed as possible. In order to accomplish this it is desirable to plow in the fall, provided that blowing out of the soil during the winter will not be serious. If the soil is left rough, danger from blowing will be reduced. Sometimes very early spring plow-

Fig. 2.—Mixed stand of grasses in foothills at elevation of about 5,500 feet. A dryland pasture would succeed here but it is questionable whether the pasture plants would be of greater value than the range plants. August 21, 1927.

ing and leaving the soil rough until seeding time later in the spring. is advantageous. Old plowed fields that have grown up to perennial weeds may be plowed, or in places it may be better to get rid of the weeds by thoro disking. Plowing or disking at right angles to the direction of the prevailing winds will often eliminate blowing out of the soil.

Seeding Methods

The most efficient method of seeding is drilling the seed in well-prepared soil. Covering the area with two drillings at right angles to each other results in a better cover of plants than drilling in only one direction. Broadcasting the seed followed by thoro harrowing with a spike-toothed harrow is another, but much poorer, method. Much seed has been wasted in broadcasting when not followed by harrowing or by inefficient harrowing with brush and other makeshifts.

It appears that the best time to sow the mixture given below is as early in the spring as possible.

Kinds of Plants to Sow

The kind of plants to sow depends largely upon local conditions of soil and moisture and upon the uses to which the pasture will be put. Cattle and horses relish some kinds of plants that sheep do not care for. Dryland species particularly well adapted for cattle and horses are slender wheat grass, (Fig. 3), (called western wheat grass or western rye grass by seed dealers), crested wheat grass, smooth brome grass (Fig. 4) and bulbous blue grass. The first two do not appear to be very valuable for sheep, but the latter two are. These species, particularly crested wheat grass and bulbous blue grass, are especially valuable for their early spring growth. Some of them grow well again in the fall. All are adapted to considerable summer drouth. Yellow sweet clover may well be added in many places to increase the amount of summer forage and to have a legume in the stand.

The amount of seed of each species to sow will depend largely

Fig. 3.—Slender wheat grass growing without irrigation near Fort Collins. A good pasture or hay plant for cattle and horses. July 8, 1929.

Fig. 4.—Smooth brome grass growing without irrigation near Fort Collins. It furnishes excellent pasturage for all classes of stock. July 8, 1929.

upon the availability of the seed. A preliminary recommendation of a mixture for a pasture for cattle and horses is: Crested wheat grass 4 to 5 pounds per acre, slender wheat grass 5, brome grass 5, bulbous blue grass 3, yellow sweet clover 2, totaling 20 pounds per acre. The mixture for sheep is less satisfactory consisting of brome grass 12 pounds per acre, bulbous blue grass 5, and yellow sweet clover 3.

Seed of smooth brome grass, slender wheat grass and yellow sweet clover may be obtained from most seed dealers. Bulbous blue grass seed may be secured from Mrs. H. P. Bush, 826 E. Main St., Medford, Oregon. Seed of crested wheat grass may be secured from Oscar H. Will and Company of Bismarck, North Dakota; Fargo Seed House, Fargo, North Dakota; Valker-Christensen Company, Minot, North Dakota.

Descriptions of Grasses

Crested wheat grass was first introduced to the United States from Russia in 1898. It is a native of the steppe region of Russia and southwestern Siberia. Little attention was given to it until 1915. Since then it has been demonstrated that this grass is one of the most drouth-enduring and earliest growing of the perennial grasses. It is reported to be about a month earlier than native grasses and from 1 to 2 weeks earlier than brome grass. It has sometimes yielded more than either brome or slender wheat grass. If planted alone, 10 pounds per acre are recommended. It is an erect bunch grass. During the first season it stools out rather rapidly and usually forms a small amount of seed, (Fig. 5). In later years 200 to 800 pounds of seed per acre may be secured. A fair average yield is considered to be 300 to 400 pounds per acre. Instructions for growing this grass for seed may be secured from the Northern Great Plains Field Station at Mandan, North Dakota.

Bulbous blue grass, also called winter blue grass and bulbosa blue grass, has been introduced into Oregon, California, Colorado and probably other western states, usually, it is believed, with alfalfa seed. It is highly relished by stock and it is very nutritious. In Oregon and California it grows during the winter and dries to the ground in the summer. It is a perennial. In Colorado it grows very early in the spring, blooms in May and then dries up later. In place of flowers or seed, it produces small bulbs or bulblets. It also produces basal bulbs. These bulblets are handled as seeds, sowing at rate of about 10 pounds per acre when seeded alone. This grass is rather slow to become established but it forms a good turf in time.

Slender wheat grass (Fig. 3), also called western wheat grass and western rye grass, is a perennial that is very resistant to both drouth and cold. It is a native of western North America. It is an erect bunch grass. This grass has been used extensively in western North Dakota and in Canada, especially for hay. As forage it is palatable and nutritious especially to cattle and horses.

Smooth brome grass (Fig. 4), also called Hungarian, Austrian or awnless brome grass, is a native of central Europe and Asia. It has been much used in western United States and Canada because of its resistance to drouth, earliness of growth, abundant production of forage thruout the season, palatability to all classes of stock and because of its method of spreading by underground rootstocks. It is a perennial, forming a fairly open turf.

Care After Planting

A good stand of plants may be ruined the first season by improper treatment. It is important to pay especial attention to the surface

the first season in order to secure the best possible stand. Grazing should not be permitted until towards the close of summer when light grazing does not appear to cause any damage if the soil is dry. The weeds should be mowed as soon as they begin to hinder the growth of the grasses. Many pastures have been greatly damaged the first year by failure to mow the weeds in time. If a so-called nurse crop has been used it should also be cut as soon as it begins to hamper the growth of the seedlings, long before the nurse crop begins to bloom. Excessive trampling, especially when the soil is wet, should be prevented. Bulbous blue grass appears to be easily killed by exposure of the crowns by trampling or erosion. Too close grazing should be avoided. After the plants have become established rotation or alternate grazing of two or more pastures will, as a rule, result in greatest forage yields with least injury to the stand.

Report of Experimental Work on Mountain Pastures

Near Fort Collins, elevation about 5,000 feet.—A number of grasses and legumes were planted in rows during the last week of

Fig. 5.—First-season stand of crested wheat grass at an elevation of about 6,300 feet near Livermore. July 15, 1927.

April, 1928, on an old plowed area that was rather gravelly. It was located at the base of the foothills and received no irrigation water. The only early species were crested and slender wheat grasses and bulbous blue grass. The two former became nicely established the first year, the last was much slower. All continued to grow very nicely during the second season. On March 6, 1930, the crested wheat grass tufts were dense with numerous green leaves in each tuft. The new growth was 2 to 5 inches tall. Slender wheat grass had somewhat fewer green leaves that were 2 to 4 inches tall. The bulbous blue grass clumps were very dense and mat-like, covered with green leaves 1 to 3 inches tall. The base of the clumps was made up largely of a mass of bulbs pressed closely against each other.

Near Livermore, elevation about 6,300 feet.—An area, (about one-fourth acre) of good soil that had been in dryland potatoes was seeded in the spring of 1927 to 4 pounds of crested wheat grass. The seed was broadcast and then harrowed in. By July 15 it had made a good stand (see Fig. 5). There were up to 10 flower stalks per plant averaging 10 inches tall. On March 8, 1930, this area was being closely grazed by cattle (Fig. 6), the tufts were 2 to 4 inches in

Fig. 6.—A portion of the same crested wheat grass pasture shown in Fig. 5 but taken on March 8, 1930. It is being very closely grazed by cattle.

Fig. 7.—An area that had been in grain on which an excellent stand of pasture plants was obtained. Near Virginia Dale, 7,000 feet. March 8, 1930.

Fig. 8.—Detail on July 19, 1929, of the pasture shown in Fig. 7. The chief plants are smooth brome grass, crested and slender wheat grass, and yellow sweet clover. Seeded in spring of 1928.

diameter and there were numerous green leaves 1 to 4 inches long on each tuft. None of the native grasses, nor Kentucky blue grass and brome grass, were as far advanced.

Near Virginia Dale, elevation 7,000 feet.—In the spring of 1928 several areas were seeded to a few kinds of grasses. On one area (Figs. 7 and 8) that had been in grain an excellent stand was secured. Brome grass was most abundant but yellow sweet clover, slender wheat grass and crested wheat grass were also numerous. On another area of poor, gravelly soil, crested wheat grass was the most successful. It was spreading and gradually killing out the weeds. A third area, which had been plowed, produced good growth of crested wheat grass and bulbous blue grass. Drilling in the seed resulted in better stands than broadcasting. On another area of 12 acres where brome grass, yellow sweet clover and orchard grass had been seeded in the spring of 1925, the first two formed most of the stand. This pasture yields a large amount of forage (Fig. 1).

The earliest grasses were crested wheat grass and bulbous blue grass. On March 8, 1930 when the soil was still frozen below a depth of 4 to 6 inches, crested wheat grass was most developed, having numerous green leaves 2 to 6 inches long; bulbous blue grass also had many green leaves 2 to 6 inches long; brome grass and slender wheat grass had fewer green leaves 1 to 3 inches long and orchard grass had but few green leaves about 1 inch long. The clumps of most of the grasses were 2 to 4 inches in diameter. Most of the grasses, except orchard grass, were being closely grazed by cattle.

Conclusion

There is a distinct need for early pastures in the mountainous parts of Colorado. Experimental work conducted during the past three seasons in a number of areas indicates that certain grasses are valuable for both spring and fall pasture.

A mixture of grasses that are from 2 to 4 weeks earlier than native grasses has been found to meet the need for early pasturage in several places. For cattle this consists of crested wheat grass, 4 to 5 pounds per acre, slender wheat grass 5, brome grass 5, bulbous blue grass 3, yellow sweet clover 2, totaling 20 pounds per acre. Since the first two do not appear to be very palatable for sheep, the mixture recommended for them is brome grass 12 pounds per acre, bulbous blue grass 5 and yellow sweet clover 3.

It is emphasized that considerable attention must be given to the location of the pasture, preparation of soil for planting, seeding and later treatment of the pasture, in order to secure the best possible results.

Because of the importance of this early pasture problem, it appears advisable to publish the available information as a progress report of our observations and experiments to date.

Bulletin 361 April, 1930

THE COST OF LOCAL GOVERNMENT

IN LARIMER COUNTY, COLORADO

BY G. S. KLEMMEDSON

In Cooperation with the Division of Finance, Bureau of Agricultural Economics, U. S. D. A.
Washington, D. C.

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Preface

The Colorado Agricultural College has recognized the need for a study of local government in Colorado for the purpose of aiding the agricultural interests of the state that carry the largest burden of taxation.

It is believed that, in the solution of everyday problems of the local government that practical illustrations of savings thru research into county affairs would stimulate the adoption of improved methods designed to increase the efficiency of local government.[1]

A preliminary study of Larimer County government was started in June, 1926, by Burton D. Seeley, a graduate student in the Department of Economics, under the direction of Professor L. A. Moorhouse. The study resulted in a master's thesis entitled "Taxes as They Affect the Rural Taxpayer." County officers cooperated freely with Mr. Seeley in making the study.

The Economics Department of the college, on its own behalf and on behalf of the college, desires to thank the Division of Finance, Bureau of Agricultural Economics, for its constructive aid in preparing this report. It also wishes to thank Rolland A. Vandegrift, director of research, California Taxpayers Association, for his assistance in outlining methods of research used in similar studies in California. It takes this opportunity to express appreciation to the Board of County Commissioners for reading and criticizing the entire manuscript and all the officials and employees of the county whose cooperation made possible this study. The author has also attempted to express in the bulletin, as occasion arose, obligation to many others from whom many suggestions were derived.

[1]Since the study was completed many of the suggestions for improving the efficiency of the county government have been adopted by the new board of commissioners. Attention has been called to these changes in the footnotes wherever possible. The commissioners are powerless to make certain other changes recommended until the present 50-year-old state constitution is amended or revised, but they should be given credit for an attempt to improve conditions.

Summary

Efforts to improve the status of farmers in our tax structure should include a determined effort to secure greater economy in local expenditures.

This study indicates opportunities for improvements and savings thru greater efficiency: (1) In handling records and accounts; (2) by pointing out the necessity for suitable systems of budgeting to make public scrutiny of expenditures more effective and give the public a better understanding of the uses of their funds; (3) by showing the need for a centralized purchasing department; (4) by recommending the reorganization and consolidation of related departments; (5) by pointing out need for a careful study of school indebtedness; (6) by indicating bad features in the present methods of financing education; (7) by showing that many public improvements and services—roads, schools, etc.—are perhaps less local in character than generally thought, and that the movement to finance them by taxes levied on larger territorial units should be accelerated; (8) by showing the need for some method of controlling the increase in public debt; and (9) by pointing out many other methods and devices aimed at economy.

There can be no adequate reform of taxation which does not rest upon an intelligent and scientific examination of public expenditures, governmental organization and administrative efficiency.

The reader will find a brief summary at the end of each section discussed.

THE COST OF LOCAL GOVERNMENT

IN LARIMER COUNTY, COLORADO

BY G. S. KLEMMEDSON

Why a Study of Local Government?

The cost of local government has been rising so rapidly in the past few years, the present burden is so great and the prospects for reduction are so remote, as to thrust the problems of local government into the forefront in Colorado.

These are the days when local governments as well as individuals feel the economic pressure and financial stress. It is a time when everybody preaches but few practice economy. At such a time it is natural that the question should be raised, as to: (1) Whether too much money is being spent by our counties on public schools, roads and general county government; (2) whether such funds are economically administered; (3) whether the cost of services demanded is distributed fairly according to the benefits received and the ability of the taxpayer to pay for them; and (4) how the taxpayer's money is being spent.

The relation of taxation to agriculture cannot be explained fully in terms of direct taxes on farm property. It is also necessary to take into account the farmer's position in our tax structure as a whole and his relation to public improvements and services. The farmer, while unable to shift his taxes to others, is obliged under our present system to pay a part of the taxes of others. Efforts to improve the status of farmers in our tax structure should include a determined effort to secure greater economy in state and local expenditures.

In the final analysis the amount of taxes raised is not so important as knowledge of whether the funds so derived are efficiently spent, what quantity and quality of services and benefits the residents of a community receive in return for taxes paid.

Most of us realize that taxes confer many benefits. Higher taxes in one community than another may mean better roads, superior educational facilities, better-equipped libraries and better police and fire protection. Who can say that these are not worth the price?

Why We Have the Problem of Increasing Cost of Local Government

The increasing costs of local government are due to several reasons:

First, there are certain prominent defects in the organization and management of the local government which result in high costs. These will be pointed out and discussed.

Secondly, the inertia with which the public nearly everywhere views county governments has not been broken down. This inertia is in large part due to lack of information about county government and a failure to realize its importance. Partisan considerations interfere with efforts of public-spirited citizens and officials. All attempts at improvement whether they are for reorganization of county government, establishment of financial control, or other means of improvement meet with political opposition or indifference .

In Larimer County, as well as many other counties in Colorado, the method of conducting the business has grown up thru practice over a long period of time and now needs modernization.

Little information as to methods and costs to determine improved methods and economical procedure has been or is at present available. With the rising need for services of all sorts some practices in administration and in accounting have grown up without proper coordination.

Seldom have the administrators of the different departments of the government known what it has been costing them to perform services, as in the case of the per-mile cost of maintaining or constructing roads of different kinds, the cost of operating highway equipment, the cost of handling tax records, the per capita cost of teaching various subjects in schools, or the cost per patient in the county hospital.

Without adequate information as to costs, quality of service, and comparable data from other counties or schools to guide them in controlling costs, the administrators could not intelligently exercise control and make desirable changes. The taxpayers, having much less information than the officials, could not give assistance or lend such moral support as the importance of the problem warrants.

Plan and Purpose of This Study

This study is made for the purpose of showing where all funds spent by the county came from, how they were expended, and what was secured for the expenditure, so that the taxpayer can see where his money went and what was secured for it.

It will be a long time before all of the information needed to do this is available in a desirable form. But in the present bulletin a beginning has been made in this direction, and accordingly emphasis has been placed upon such subjects as: (1) The sources of tax and other revenue; (2) the purpose for which expenditures are made; (3) the cost of bond issues; (4) the reasons for the increase in floating indebtedness; and (5) a study

of governmental organization and administration to see where it can be improved.

If public attention were increasingly directed to such matters, it would better appreciate the need of making the government an efficient one.

The author wishes it clearly understood that he is dealing with principles of government rather than with personalities in making this study for the years 1920 to 1928. This research is directed toward the betterment of present methods and not for spying upon the work of public officials. Public officials should receive constructive recommendations about how they can improve or reduce the cost of service.

The Solution of the Problem

Obviously the solution of this important problem of local taxation is in making the local government and all its departments efficient.

How Can the Taxpayer Control Local Expenditures?

It is natural that the taxpayers will show a greater interest in government and will complain less about high taxes if they can trace public expenditures with ease by means of the budget. There is no reason why the taxpayers of Larimer County or any other county should not help prepare the budget estimates.

After the commissioners have drafted a tentative budget, it could be published and then a day might be set for hearings. With copies of the previous year's budget in their hands, the citizens could be asked to come in and obtain an explanation of every increase or decrease. They could voice their disapproval of any item that seemed to them unnecessary. The budget at least offers the people a chance to participate in shaping governmental policy in a very effective way.

There should be complete publicity of all county affairs. The annual reports and financial statements required by law are not very enlightening to the average citizen. A county accountant or other official who can take these reports and explain them in an elementary way can render a very valuable service to the county. Most official transactions are reported by the newspapers, but oftentimes these items would be better understood if there could be an official word of explanation. Besides, there is apt to be a certain amount of secrecy about public affairs and essential facts are often concealed.

The individual can do little by himself, but a small group of people, armed with accurate information and animated by right ideals, can exert a tremendous influence.

The Material and Method Used

The study covers selected years from 1920 to 1928. Receipts and expenditures in the study covering 1928 are taken from the auditor's report which gives a consolidated statement of all departments of the county showing all sources of revenue. The expenditures for 1928 are shown both as cash expenditures and those based on the amount of warrants issued during the year. Warrant ledgers together with other records and accounts, were examined and used whenever necessary.

Personal visits were made to study systems of accounts, budgets, photostatic recording, machining of tax records, the use of mechanical methods in handling financial records, and other improved methods used in El Paso and Weld counties, and in Denver.

The results of research in county government in North Carolina were obtained thru correspondence with Dr. E. C. Brooks, chairman of the County Government Advisory Commission, Raleigh, North Carolina. An analysis of the expenditures of county government in California was obtained thru the California Taxpayers' Association. The author is especially indebted to these and other leading authorities such as Paul W. Wager, University of North Carolina, for valuable aid in the preparation of this manuscript. They have long been calling attention to county government and its antiquated and wasteful practices.

THE ECONOMIC WEALTH OF LARIMER COUNTY

The ability of a community to satisfy its desire for better schools, roads and other services, rests ultimately upon its income. In the long run it cannot sustain expenditures of greater amount than its income, and if progress is made, expenditures must be less than income so that a surplus is provided for capital accumulation. Unfortunately the available information respecting both wealth and income are so fragmentary and inaccurate that attempts at measurements can be no better than good estimates.

Several sources of information are available concerning the amount of certain types of wealth in Larimer County as follows: The federal census, the biennial census of manufactures, the 1925 agricultural census, the assessment figures, the Colorado yearbook, and miscellaneous sources.

Owing to the fact that property in general is assessed at only a fraction of its actual value, the assessment figures cannot be taken as a fair measure of the wealth of Larimer County. From information derived from various sources, the estimates of the ratio of assessed to actual value vary from 5 percent on intangibles to 60 percent on real estate.

Applying these ratios to the figures obtained from the assessor, the actual value of taxable wealth would appear to be approximately 159 million dollars for 1928. It should be clearly understood that nothing is claimed for these figures beyond that of being rough estimates.

1,260,000 lambs were fed in Northern Colorado in 1928

16,600 acres of sugar beets valued at $1,507,300 were produced in Larimer County in 1928

TABLE 1.—STATISTICS CONCERNING LARIMER COUNTY, 1928

Estimated Wealth of County:	Total	Per Capita[1]
Realty:		
Urban (cities)		
Land	$10,000,000	$ 336
Improvements	18,000,000	604
Rural		
Land	30,000,000	1,008
Improvements	5,000,000	168
Public utilities and factories	12,000,000	403
Mineral resources, oil, limestone	12,000,000	403
Personalty:		
Tangible		
Livestock	12,000,000	403
Automobiles	4,000,000	134
Farm machinery	2,000,000	67
Manufacturers' stocks	10,000,000	336
Mercantile stock	10,000,000	336
Public utility	1,000,000	37
Household	3,000,000	100
Intangible		
Money	10,000,000	336
Stocks	5,000,000	168
Bonds	10,000,000	336
Mortgages and notes	5,000,000	168
Full value of taxable property	$159,000,000	$5,343
Estimated annual gross income:		
Income from crops, livestock and livestock products, 1928	$7,000,000	$ 235
Wages to agricultural workers	1,200,000	40
Wages to manufacturers' workers	1,500,000	51
Value added by manufacture	6,000,000	202
Mercantile	5,000,000	168
Stocks, bonds, rents, interest, etc.	2,000,000	67
Total income	$22,700,000	$ 763

[1]Based on population of 29,760 in 1928.

TABLE 2.—SUMMARY OF THE VARIOUS PRIMARY FACTS RELATIVE TO LARIMER COUNTY'S TAXABLE ABILITY

Total area, acres	1,682,560
Total population 1928 (estimated)	29,760
Total population (1925 census)	29,340
Children of census age (6-21)	9,628
Estimated gross wealth of Larimer County's population (1928)	$159,000,000
Estimated total annual income of Larimer County	$22,700,000
Total taxes raised in Larimer County, 1928	$1,322,377
Total assessed value Larimer County, 1928	$55,590,465
Average property tax rate (total taxes divided by total assessed property)	2.38%
Average property tax rate (total taxes divided by total wealth)	.83%
Percentage of estimated total income taken for local and state property tax	5.9%
Estimated gross wealth of population per capita	$5,343
Estimated annual income of population per capita	$763
Estimated annual income of population per family of 4	$3,052
Per capita taxes, excluding cities and towns	$44.43
Per family taxes	$177.72

High school recently built for the city of Fort Collins

Summary

Information respecting the wealth of Larimer County is so fragmentary that attempts at measurement can be no better than rough estimates.

The value of taxable wealth is approximately 159 million dollars for 1928.

The estimated gross wealth per capita is $5,343.

The estimated annual gross income per capita is $763 and per family of four $3,052.

The taxes paid per family amount to an average of $178 per year.

HOW LARIMER COUNTY TAX REVENUES AND OTHER RECEIPTS ARE DISTRIBUTED

Purpose for Which Revenue Is Expended

The following discussion will give a brief description of the various purposes for which state, county, and school revenues are expended.

The ordinary county revenue consists of tax collections; fees from the county treasurer, county clerk, sheriff, county court, district court and justice of the peace court; interest from delinquent taxes and county money on deposit; licenses; and miscellaneous receipts. This fund is used for general county expenses.

Road receipts consist of tax collections, state and federal aid, 50 percent of the motor vehicle tax less cost of collection, a portion of the state gasoline tax apportioned according to the mileage of state highways within the county, and fines for violation of traffic laws, royalties on forest and mineral leases, and accommodation sales to citizens of the county.

The revenues for the operation of the schools are derived from three main sources. The largest revenue is derived from district school tax levies. The directors in each district make annual budgets of funds required and their budgets are certified by the county superintendents to the county commissioners, who make levies thru the regular tax-collecting channels. In addition, the state is a large owner of school lands, from the sale and operation of which funds are derived. These revenues are maintained in a permanent school fund and the interest therefrom becomes available for the support of the state educational institutions. The third source of revenue is from tax levies made by counties under a minimum teachers' salary law which is limited to not to exceed 5 mills a year.[1] Small amounts are also received from certain fines.

The hospital, poor farm and county home secure revenue from ordinary tax collections and from receipts from the county hospital and poor farm. These sources provide funds for the care of unfortunates within the county and support the county hospital and poor farm.

The state reimburses the county for one-half of its expenditures for the blind from a special fund secured for that purpose. This fund provides a maximum of $300 per person per year for all those within the county who qualify under the state law.[2]

[1]Compiled Laws of Colorado, 1921, Sec. 8451, S.L.1927, p. 640.
[2]Compiled Laws of Colorado, 1921, Sec. 725 and 730.

The mothers' compensation fund provides for the assistance and protection of women who are unable to properly care for their children, or who are unable to properly care for themselves and infant child or children during certain periods before and after childbirth.[1]

Special advertising revenue is raised by taxation to advertise the county and the disposition is at the discretion of the county commissioners. It is used chiefly to afford advertising thru the local chamber of commerce and the county fair.

Tax Levies in Larimer County Increase

The tax levy in Larimer County rose from $9.58 in 1924 to $12.37 per $1000 assessed valuation of property in 1928. The distribution of the tax levy for each year was as follows:

TABLE 3.—DISTRIBUTION OF LARIMER COUNTY TAX LEVY

Object of Levy	Dollars tax per $1000 assessed valuation of property 1928	1924	Percentage increase
For ordinary purposes	$2.00	$2.25	—11*
Support of poor, county hospital and home	1.00	.45	122
Road purposes	3.40	2.75	24
Special advertising	.07	.04	75
Liquidation of warrants	1.60	.25	540
General school purposes	4.00	3.33	20
Interest on county bonds	.14		
Mothers' compensation	.12	.20	—40*
Blind	.04	.06	—33*
Poor-farm heating plant		.25	
Totals	$12.37	$9.58	29

Note the large increase in the levy for the payment of unpaid warrants, support of the poor, special advertising, road purposes and general schools. Levies for ordinary purposes, mothers' compensation and the blind decreased.

From the distribution in 1928 it will be seen that the largest single levy is for school purposes, $4; for road purposes, $3.40; and for ordinary general government, $2. These three levies make up three-fourths of the total county levy.

The valuations have remained practically the same during this period. The valuation for 1928 was $55,590,465.

State tax levies which should be added to the county tax were distributed to the various funds based on a total valuation of $1,577,560,380 for 1928 and $1,540,500,479 for 1924 as follows:

[1]Compiled Laws of Colorado, 1921, Sec. 608 and 609.

*Represent decreases.

TABLE 3a.—DISTRIBUTION OF STATE TAX LEVY

Purpose of Levy	Dollars tax per $1000 assessed valuation of property	
	1928	1924
State purposes (General Revenue)	$ .43	$ .42
State University	.52	.43
Agricultural College	.26	.21
Agricultural College, Experiment Station	.07	.07
Fort Lewis School	.05	.04
School of Mines	.16	.13
School of Mines, Experiment Station	.02	----------
State Teachers College	.26	.21
Western State College (Gunnison Normal School)	.10	.08
Mute and Blind School (Colorado Springs)	.14	.14
Colorado State Hospital	.27	.27
Stock Inspection	.03	.03
Capitol Building	.10	.10
Educational Institutions Buildings	----------	.30
State Roads	.50	.50
State Fair Tax	.03	.01
Improvement Tax on State Property	----------	.02
Interest on Funding Bonds, 1910	.03	.03
Interest on Insurrection Bonds, 1909, 1914	.02	.03
Interest on State Highway Bonds, Act 1921	.16	.17
Sinking Fund on State Highway Bonds, Act 1921	......	......
Capitol Office Building	.16	.12
State Military	.07	.07
Blind Benefits	----------	.09
Sinking Fund, Funding Bonds, 1910	.03	.03
University Medical School and Nurses Training School	.10	.05
Sinking Fund Insurrection Bonds, 1909	----------	.13
School Fund Reimbursement	----------	.01
Adams State Normal	.05	.01
Totals	$3.56	$3.70

State taxes paid by residents of Larimer County per $1000 valuation of assessed property decreased from $3.70 in 1924 to $3.56 in 1928. Of the $3.56 which the state receives from Larimer County, 43 cents are used for general state purposes, 52 cents for the State University, 26 cents for the Agricultural College and 7 cents for the experiment station, or $1.73 is allotted for all state educational institutions.

Trend of Revenue Collections Rising

Information and attention have been directed in the previous section to the purpose of tax collections, the functions for which

collected, and the classes of property which bear these burdens. It shall be the purpose of this section to analyze in detail all receipts collected by the county and show the purpose for which taxes are levied and collected.

Before we discuss the revenue receipts for 1928 it might be well to consider what has taken place during the past few years so that the reader may have a picture of the trend of receipts and tax collections.

During the year 1928 the receipts from current tax collections, excluding tax from cities, amounted to $1,322 thousands, as against $812 thousands in 1920. See Table 4. The current tax collections increased $510 thousands, or 62.8 percent as compared with 1920.

Tax collections for state purposes amounted to 15.8 percent of the total tax collections in 1928 compared with 20.9 percent in 1920. Their proportion of the total showed a decrease of 5.1 percent from 1920 to 1928.

Educational taxes in 1928 comprised 53.5 percent of the total tax collections. Their proportion of the total showed an increase since 1920 when they had amounted to 45.3 percent of the total.

Road taxes amounted to 12.4 percent of the total in 1928 and 15.6 percent in 1920. This indicates a decrease in taxes collected for roads. Expenditures on roads during this period, however, tell a different story.

General government receipts comprised 14.9 percent of the total in 1928, which is only .1 percent higher than in 1920.

Tax collections for charities, the hospital and county farm amounted to 3.4 percent of the total in 1928, an increase over 1920, when they amounted to 2.8 percent.

Increase Due to Education, Roads, Poor and Debt

An analysis of the figures in Table 4 shows that the large increase in taxation is due primarily to increased expenditures for educational purposes, highways, poor and for the liquidation of floating debt.

A study of the receipts from all sources of revenue for Larimer County from 1924 to 1928 is shown in Table 5. It shows that educational revenue has increased $133 thousands from 1924 to 1928, charities revenue from $55 to $86 thousands, general government revenue from $156 to $259 thousands, and city and town revenue from $291 to $342 thousands. Revenues

TABLE 4. DISTRIBUTION OF CURRENT COUNTY TAXES IN LARIMER COUNTY, COLORADO, 1920 AND 1928

Purpose of Tax Collection	Thousands of Dollars		Percentage distribution	
	1920[1]	1928	1920	1928
State purposes	170	209	20.9	15.8
Education:				
Special school fund	281	435	34.6	32.9
General school fund	49	169	6.0	12.8
Interest on school bonds	21	56	2.6	4.2
Redemption of school bonds	17	47	2.1	3.6
Total	368	707	45.3	53.5
Roads and highways	127	164	15.6	12.4
General government:				
Ordinary county	98	98	12.1	7.4
Liquidation of unpaid warrants	20	87	2.5	6.6
Special advertising	1	4	.1	.3
Interest on county bonds	1	8	.1	.6
Total	120	197	14.8	14.9
Charities and hospitals:				
Poor fund, hospital, county farm	18	38	2.2	2.9
Mothers' compensation	4	7	.5	.5
Blind benefit	1	....	.1	....
Total	23	45	2.8	3.4
Unforeseen contingency	2	....	.3	....
Special local assessment	2	....	.3	....
Total from tax collections	812	1322	100.0	100.0

collected for the state decreased from $247 thousands to $211 thousands, indicating that the state is obtaining an increasing portion of its revenue from other sources than from taxation on general property. The amount of revenue collected for the payment of outstanding warrants increased from $13 thousands to $88 thousands. Revenues collected for road expenditures increased during 1925, 1926 and 1927, but showed a decrease during 1928.

A study of the outstanding floating indebtedness will show that expenditures have exceeded income every year since 1923. The road expenditures greatly exceeded the road receipts in every year from 1925 to 1928.

[1]1920. B. D. Seeley. "Taxes as They Affect the Rural Taxpayer." Thesis Colo. Agr. Col. 1928.
Note: Receipts from delinquent tax and miscellaneous sources omitted.

HOW LARIMER COUNTY CURRENT TAX COLLECTIONS ARE DISTRIBUTED

Total Collections $1,322,377 in 1928

CHART 1

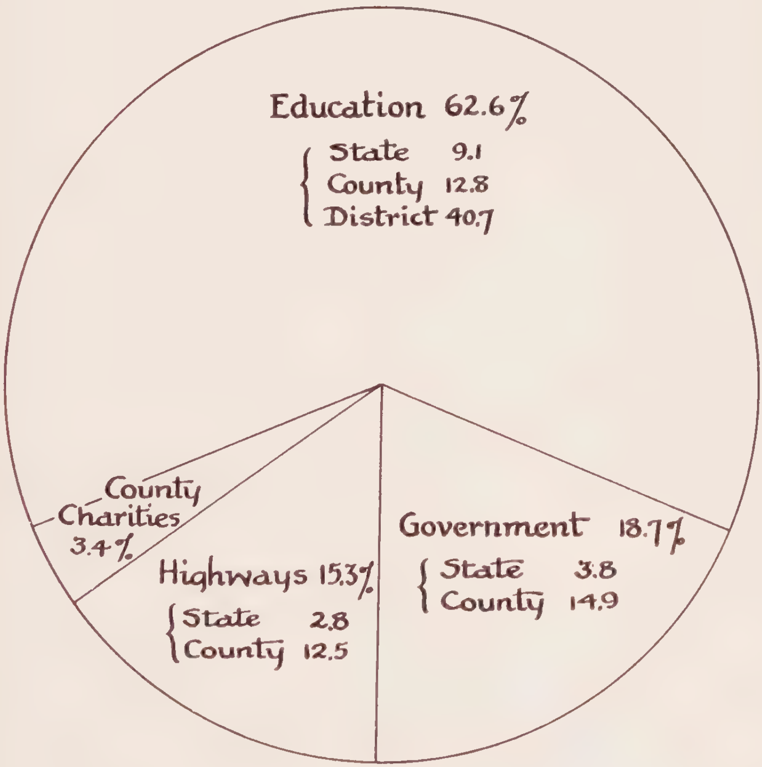


TABLE 5.—DISTRIBUTION OF RECEIPTS FROM ALL SOURCES: LARIMER COUNTY, 1924 TO 1928[1]

Purpose of Collection	Amounts in Thousands of Dollars					Percentage Distribution				
	1924	1925	1926	1927	1928	1924	1925	1926	1927	1928
State purposes:	247	194	207	202	211	13.5	10.4	10.8	10.1	10.7
County purposes:										
General government										
Ordinary county expenses	118	145	138	141	138					
Liquidation of unpaid warrants	13	68	84	88	88					
Redemption of bonds	......	......	......	......	......					
Interest on bonds	......	4	9	8	8					
Special advertising	2	4	2	4	4					
Advertising tax sales	1	1	1	1	......					
Interest on delinquent tax	15	11	14	14	13					
County treasurer's cash fees	2	2	2	3	3					
Bank interest	5	11	6	6	5					
Total	156	246	256	265	259	8.5	13.1	13.4	13.2	13.1
Charities										
Poor farm, county home and hospital	38	35	40	75	80					
Blind benefit	7	8	7	5	......					
Mothers' compensation	10	6	7	6	6					
Total	55	49	54	86	86	3.0	2.6	2.9	4.3	4.4

[1]Auditor's report.

TABLE 5.—DISTRIBUTION OF RECEIPTS FROM ALL SOURCES: LARIMER COUNTY, 1924 TO 1928[1]—(Continued)

Purpose of Collection	Amounts in Thousands of Dollars					Percentage Distribution				
	1924	1925	1926	1927	1928	1924	1925	1926	1927	1928
County purposes:										
Roads										
General property taxation for roads	144	174	179	149	165					
Gasoline tax	24	26	27	45	27					
Motor vehicle license	22	27	26	29	31					
State highway	53	43	36	40	15					
Fines	1	1	2	1	1					
Forest service	4	7	.....	4	6					
Miscellaneous	3	10	3	5	3					
Total	251	288	273	273	248	13.7	15.4	14.3	13.7	12.6
Education										
General	197	204	215	209	198					
Special	372	413	420	430	457					
Interest on bonds	48	55	69	53	57					
Redemption of bonds	9	27	34	56	47					
Total	626	699	738	748	759	34.1	37.4	38.7	37.4	38.5
Sundry miscellaneous										
Tax redemptions	28	37	39	42	40					
Motor vehicle	.....	.....	.....	35	28					
Hospital bond sale	179	.....	.....	.....	.....					
Total	207	37	39	77	68	11.3	2.0	2.0	3.8	3.4
City and Town										
General tax	193	243	265	250	254					
Special assessments	98	115	76	100	88					
Total	291	358	341	350	342	15.9	19.1	17.9	17.5	17.3
GRAND TOTAL	1,833	1,871	1,908	2,001	1,973	100.0	100.0	100.0	100.0	100.0

[1]Auditor's report.

Education takes more than half of the county tax dollar. Out of every dollar raised for educational purposes by taxation 13 cents was raised by county taxation, 41 cents was raised by district taxation, and 9 cents by state tax, a total of 63 cents. Education was therefore supported to a greater degree by district taxation than by general county or state taxes. Chart 1.

Roads and highways constitute the next largest purpose except for general government, for which funds were raised by taxation. The major portion for this purpose was raised by county taxation. The total raised by county taxation for road and highway purposes was 12 cents and for state 3 cents, making a total of 15 cents out of every dollar derived from taxation. In addition to the actual amount of money raised by taxation for roads, large sums of money were received from the gasoline taxes and motor vehicle licenses. A large floating debt was incurred for building and maintaining roads because revenues were insufficient.

Current tax collections, delinquent tax and miscellaneous receipts from other sources are given for 1928 separately in Table 6. Funds collected by the county for cities and towns in Larimer County are also shown.

Table 6 shows that current-year tax collections amounted to 84.2 percent of the total revenue, delinquent tax .6 percent, and miscellaneous receipts 15.2 percent. Information is also given on the amount of funds received from different sources; as for example, in the road receipts the amount derived from property taxes, gasoline tax, motor vehicle, license fees, state highway department, fines and Forest Service are given separately.

Summary

Tax levies in Larimer County have increased from $9.58 per $1000 of assessed valuation in 1924 to $12.37 in 1928 while the valuation has remained practically the same.

The purpose of the state tax levy is given in detail for 1924 and 1928 and shows that it has decreased from $3.70 per $1000 assessed valuation in 1924 to $3.46 in 1928.

Receipts from current tax collections have increased from $812,000 in 1920 to $1,322,000 in 1928.

Educational taxes, exclusive of state taxes, comprised 53.5 percent of the total tax collections in 1928. Their proportion of the total showed an increase since 1920 when they amounted to only 43.3 percent of the total.

TABLE 6.—HOW LARIMER COUNTY TAX AND NON-TAX REVENUES WERE DISTRIBUTED IN 1928[1]

Purpose for Which Revenue was Collected	Source of Revenue: Current Year Tax Collections	Delinquent Tax Collections	Misc. Receipts from Other Sources	Total County Receipts
State:	(1)	(2)	(3)	(4)
General state fund	$ 209,407.01	$ 1,534.43	$	$ 210,941.44
County purposes:				
General				
Ordinary government	98,159.56	756.14	44,509.60	143,425.30
Liquidation warrants	87,252.90	642.80		87,895.70
Redemption county bonds		1.70		1.70
Interest on county bonds	7,634.63	57.43		7,692.06
Special advertising	3,817.32	27.08		3,844.40
Advertising sales			727.15	727.15
Interest on delinquent tax			12,680.01	12,680.01
County treasurer's cash fees			2,702.98	2,702.98
Total	$ 196,864.41	$ 1,485.15	$ 60,619.74	$ 258,969.30
Charities				
Poor, hospital, etc.	$ 38,173.16	$ 281.98	$ 40,796.45	$ 79,251.59
Blind benefit		11.78		11.78
Mothers' compensation	6,543.97	50.68		6,594.65
Total	$ 44,717.13	$ 344.44	$ 40,796.45	$ 85,858.02
Roads and highways				
Property tax	$ 163,599.20	$ 1,162.82	$	$ 164,762.02
Gas tax			27,000.74	27,000.74
Auto vehicle license			31,310.18	31,310.18
State highway			14,882.65	14,882.65
Fines			1,170.08	1,170.08
Forest service			6,179.79	6,179.79
Miscellaneous			2,641.72	2,641.72
Total	$ 163,599.20	$ 1,162.82	$ 83,185.16	$ 247,947.18
Total for county purposes	$ 405,180.74	$ 2,992.41	$ 184,601.35	$ 592,774.50
Educational purposes				
General school fund	$ 169,052.53	$ 1,415.48	$ 27,576.05	$ 198,044.06
Special school fund	435,431.10	2,991.63	18,912.71	457,335.44
Interest on school bonds	56,448.28	427.87		56,876.15
Redemption of bonds	46,856.94	324.70		47,181.64
Total	$ 707,788.85	$ 5,159.68	$ 46,488.76	$ 759,437.29
Cities and towns				
General tax	$ 251,274.86	$ 2,343.19	$	$ 253,618.05
Special tax	88,281.66			88,281.66
Total	$ 339,556.52	$ 2,343.19		$ 341,899.71

[1]Auditor's report, 1928.

TABLE 6.—HOW LARIMER COUNTY TAX AND NON-TAX REVENUES WERE DISTRIBUTED IN 1928[1] (Continued)—

Purpose for Which Revenue was Collected	Source of Revenue: Current Year Tax Collections	Delinquent Tax Collections	Misc. Receipts from Other Sources	Total County Receipts
	(1)	(2)	(3)	(4)
Sundry miscellaneous				
Tax sale redemptions	$	$	$ 39,353.85	$ 39,353.85
Motor vehicle (county clerk)			28,321.71	28,321.71
Total			$ 67,675.56	$ 67,675.56
GRAND TOTAL	$1,661,933.12	$ 12,029.71	$ 298,765.67	$1,972,728.50
Cash balance Jan. 1, 1928				243,830.71
				$2,216,559.23
Percentage distribution	84.2	.6	15.2	100

EXPENDITURES FOR GENERAL GOVERNMENT PURPOSES

Trend of Expenditures

During the year 1928 the cash expenditures of Larimer County amounted to $2,014 thousands, as against $1,635 thousands in 1924. The cash expenditures of Larimer County increased $379 thousands or 23.2 percent during this 5-year period. Expenditures for education are the biggest single item in the local budget. Cash expenditures for education increased $163 thousands or 27.6 percent from 1924 to 1928. Cash road expenditures amounted to $265 thousands in 1928, a decrease of $11 thousands or 4 percent during this period. Cash expenditures for social welfare, that is, for the poor, blind and mothers' compensation, increased from $49 thousands in 1924 to $120 thousands in 1928, an increase of 145 percent over 1924. An analysis of the cash expenditures is shown in Tables 7 and 10.

True State of Expenditures

The analysis of the cash expenditures alone as discussed in the preceding paragraphs, fails to show the actual amount spent by the county during this period. In addition to the cash expenditures, many registered warrants were issued to be paid for in the future. Table 8 gives the amount of registered warrants issued each year for different county general government expenditures, showing the true state of affairs. A careful study of Table 8 and Chart 2 shows the reader how and where the large floating indebtedness of Larimer County originated.

[1]Auditor's report, 1928.

Purpose of Larimer County Expenditures

Chart 2

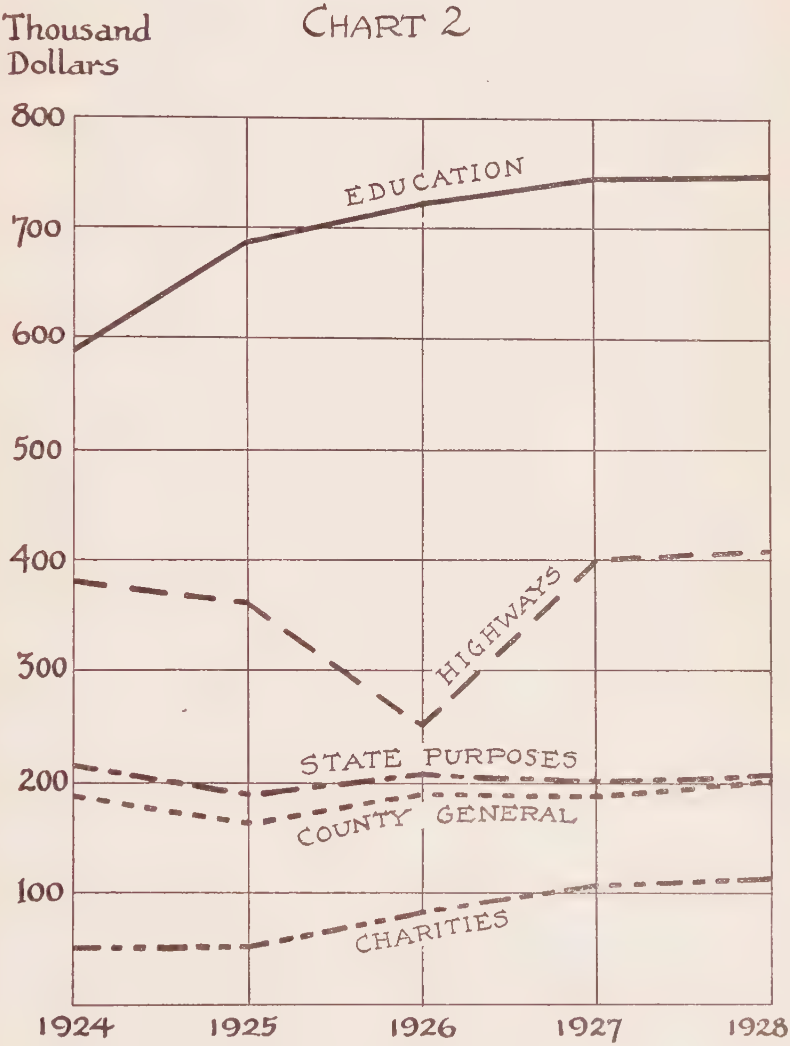


TABLE 7.—FUNCTIONAL DISTRIBUTION OF LARIMER COUNTY CASH EXPENDITURES, 1924 TO 1928

Purpose of Disbursements	Amounts in Thousands of Dollars					Percentage Distribution				
	1924	1925	1926	1927	1928	1924	1925	1926	1927	1928
State purposes										
Remittance to State Treasurer	215	191	206	202	213	13.2	9.6	10.9	10.1	10.6
County purposes:										
General government										
Ordinary	184	170	162	193	197					
Liquidation of unpaid warrants	......	32	......	......	......					
Advertising	2	4	2	4	4					
Interest on registered warrants	1	3	7	10	9					
Interest on county hospital bonds	......	8	8	8	8					
Total	187	217	179	215	218	11.4	10.8	9.4	10.8	10.8
Charities and social welfare										
Poor farm, county home, and hospital	28	32	56	81	106					
Blind benefit	8	6	5	4	4					
Mothers' compensation	13	7	7	9	10					
Total	49	45	68	94	120	3.0	2.2	3.6	4.7	6.0
Roads and highways	276	315	321	361	265	16.9	15.7	16.9	18.0	13.2
Educational purposes										
General school	196	203	222	225	215					
Special school	338	403	416	424	450					
Interest on bonds	48	56	59	59	55					
Bond redemption	9	25	27	40	34					
Total	591	687	724	748	754	36.1	34.3	38.0	37.4	37.4

TABLE 7. FUNCTIONAL DISTRIBUTION OF LARIMER COUNTY CASH EXPENDITURES, 1924 TO 1928—(Continued)

Purpose of Disbursements	Amounts in Thousands of Dollars					Percentage Distribution				
	1924	1925	1926	1927	1928	1924	1925	1926	1927	1928
Sundry										
Tax redemptions	29	35	39	44	39					
Tax rebates	1	1	1	......	1					
Canceled special tax receipts	......	......	......	......	1					
Motor vehicle license remitted to Secretary of State	......	......	......	5	58					
Capital outlay for hospital	2	169	12	......	......					
Total	32	205	52	49	99	2.0	10.2	2.7	2.5	4.9
City and Town Remittances										
Fort Collins general tax	116	164	177	164	166					
Fort Collins special tax	69	71	61	63	73					
Loveland general tax	57	54	58	53	57					
Loveland special tax	21	35	25	20	21					
Wellington general tax	5	5	6	6	7					
Wellington special tax	......	......	2	2	2					
Berthoud general tax	9	8	10	9	9					
Berthoud special tax	..	.	5	..	. .					
Estes Park general tax	7	6	8	11	9					
Timnath general tax	1	1	1	1	1					
Total	285	344	353	329	345	17.4	17.2	18.5	16.5	17.1
GRAND TOTAL	1,635	2,004	1,903	1,998	2,014	100.0	100 0	100 0	100.0	100.0

TABLE 8.—HOW LARIMER COUNTY INCREASED EXPENDITURES FOR GENERAL GOVERNMENT, 1924 TO 1928[1] (ON BASIS OF WARRANTS ISSUED)

Purpose of Issue	1924	1925	1926	1927	1928
Ordinary general county expense	$186,680.54	$181,333.14	$192,656.83	$190,859.00	$202,310.44
Roads and bridges	379,558.73	361,298.71	254,829.54	399,662.31	407,620.62
Poor and hospital	29,577.77	35,294.76	73,759.09	92,118.70	103,239.58
Mothers' compensation	13,372.00	11,985.00	8,370.00	7,560.00	6,340.00
Blind benefit	7,744.00	6,684.83	4,235.50	4,022.50	5,180.60
Advertising	1,950.00	4,366.32	1,760.00	4,160.00	6,260.00
County hospital and home buildings	2,390.71	169,115.45	....	....	....
Total warrants issued	$621,273.75	$770,078.21	$535,610.96	$698,382.51	$730,951.24

For example, in 1928 the treasurer's report shows that $265,013.15 were spent on roads; however, warrants to the sum of $407,620.62 were issued for road expenditures. The floating debt on roads was increased in 1928 from $119,174.77 to $261,-781.12, or an increase of $142,606.35, Table 28. A further discussion of this situation is given under the section of county indebtedness.

The laws of Colorado state that county expenditures are limited to the annual appropriation except for certain unforeseen contingencies and that county commissioners are held personally liable for exceeding the annual appropriation. It seems, however, that commissioners in Larimer County have been immune in the past from the penalties of the law and taxpayers have made no effort to place a check upon the expenditure of county funds.

The appropriations, income and amount of registered warrants issued in 1925 illustrate this point clearly. See Table 9, showing warrants issued in excess of income. The same thing is true of other years.

TABLE 9.—APPROPRIATIONS, INCOME AND WARRANTS ISSUED FOR THE YEAR 1925, LARIMER COUNTY[2]

Fund	Appropriation	Income	Warrants Issued	Warrants Issued in Excess of Income
Ordinary county	$151,388	$175,002.06	$181,333.14	$ 6,331.08
Poor, hospital and home	34,618	34,857.12	35,294.76	437.64
Road	270,400	287,605.33	361,298.71	73,693.38
Special advertising	4,268	4,917.50	4,366.32	....
Blind benefit	7,707	7,533.69	6,684.83	....
Mothers' compensation	6,600	6,400.20	11,985.00	5,584.80

[1]Auditor's reports.

[2]Auditor's report 1925. p 23.

Amount and Percentage of Cash Expenditures for Each Purpose - Larimer County 1928

Total Cash Expenditures $1,357,418

Chart 3

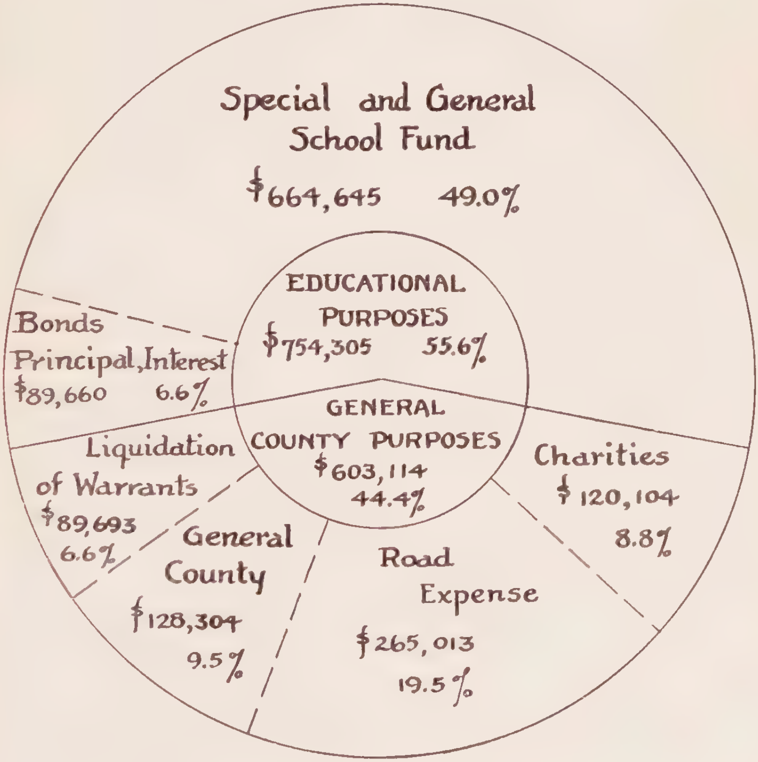


TABLE 10. HOW TAX MONEY AND NON-TAX REVENUES OF LARIMER COUNTY WERE EXPENDED IN 1928[1]

(Based on cash expenditures)

Purpose of disbursements:		
State:		
Remittance to State Treasurer	$ 212,859.20	
County:		
General government		
Ordinary government expense	107,385.75	
Liquidation of unpaid warrants	89,693.00	
Advertising	3,830.00	
Interest on registered warrants	9,206.23	
Interest on county hospital bonds	7,881.80	
	$ 217,996.78	
Charities		
Poor, hospital, county farm	$ 106,003.25[2]	
Blind benefit	4,540.60	
Mothers' compensation	9,560.00	
	$ 120,103.85	
Roads and highways	$ 265,013.15	
Total general government	$ 603,113.78	
Educational purposes		
General	$ 214,875.58	
Special	449,768.99	
Interest on bonds	55,599.74	
Bond redemption	34,060.37	
Total education	$ 754,304.68	
Total county		$1,357,418.46
City and Town Remittances:		
Fort Collins general tax	$ 166,200.40	
Fort Collins special tax	73,285.24	
Loveland general tax	56,487.62	
Loveland special tax	20,465.85	
Wellington general tax	7,041.55	
Wellington special tax	2,321.41	
Berthoud general tax	9,039.45	
Estes Park general tax	9,299.97	
Timnath general tax	1,001.40	
Total city and town	$ 345,142.89	
Sundry:		
Redemptions	$ 39,328.13	
Tax rebates	616.07	
Cancelled special tax receipts	1,381.17	
Motor vehicle license remitted to Secretary of State	57,614.12	
Total sundry	$ 98,939.49	
GRAND TOTAL ALL DISBURSEMENTS	$2,014,360.04	
Cash balance, Dec. 31, 1928	202,199.17	
	$2,216,559.21	

[1]Auditor's report, 1928.

[2]Hospital pay patients were responsible for $35,303 of this amount.

Cash Expenditures for 1928

The accompanying chart (Chart 3) shows the purposes for which Larimer County funds were expended during the fiscal year ending December 31, 1928. Remittances to the state treasurer, secretary of state, cities and towns, tax redemption and rebates are omitted. The chart is divided into two major segments: (1) Expenditures for educational purposes, including all current cash expenditures, the payment of bond redemption, and interest on school bonds; and (2) expenditures for general county purposes, including all county and district purposes which are not educational.

Expenditures for Education 56.6 Percent of Total

By comparing these two segments of the chart, it will be noted that of the total expenditure of $1,357,418.46, the expenditures for educational purposes were $754,304.68 or 56.6 percent, and expenditures for general county purposes amounted to $603,-113.78 or 44.4 percent of the total. This indicates that of every dollar expended, 56 cents went for education and 44 cents for other general county purposes.

The expenditure for roads and highways was 20 cents and for liquidation of unpaid warrants, 7 cents out of every dollar. The poor fund, blind fund and mothers' compensation amounted to 9 cents out of every dollar. Comparisons of functional costs can readily be made from the chart, for not only is the amount given for each expenditure, but also the percentage that each is of all the expenditures.

Table 10 shows the cash disbursements for the year 1928. These figures are misleading unless they are studied in connection with Table 8 which shows the amount of warrants issued for various purposes.

Issue of Warrants in Excess of Revenues a Bad Practice

The treasury warrant is the instrument by means of which all county payments are made. It becomes a means of creating short-term debt when warrants are issued in excess of the funds available for redemption. Over-drafts of this nature mean that the holders of the warrants must wait until the next tax collection period, or if this is inconvenient, they must accept such discounts as the local bankers may establish, if any. Warrants draw 6 percent interest from the time they are issued until they are redeemed. The practice followed in Larimer County amounts to borrowing to pay current expenses. The freedom with which such loans are made is a great temptation for the county officials to expand their expenditures to a level which current revenues

will not permanently support, and long-term funding of the temporary debt becomes the only alternative.

The item of salaries in the various offices of the county, when compared with such expenses as school and road expenses, is insignificant. Nevertheless, it is possible to save considerable in the matter of clerical help.

County Clerk Receipts and Expenditures

The receipts and disbursements for the year 1928 and 8 days of 1929 as reported by the county clerk and recorded were as follows:

TABLE 11.—ANALYSIS OF COUNTY CLERK'S RECEIPTS AND EXPENDITURES

Receipts:	
Recording fees	$ 10,431.08
Clerk to board of county commissioners	3,060.00
Miscellaneous fees	3,784.75
Game and fish license fees	979.75
Certificate of title fees	5,341.50
Motor vehicle licenses	108,869.23
Certificate of title (state)	1,780.50
Game and fish licenses (state)	8,533.25
	$142,780.06
Cash balance January 1, 1928	3,008.21
	$145,788.27
Disbursements:	
Paid county treasurer	$ 26,079.18
Paid to secretary of state	73,759.43
Paid game and fish commissioner	8,533.25
Paid to county clerk Ramer, cash on hand	37,163.30
Miscellaneous	253.11
Total disbursements	$145,788.27

Salaries paid by county warrant for the period January 1, 1928, to January 8, 1929, were as follows:

County clerk	$ 3,083.33
Deputy	2,033.00
Clerical assistants	16,323.65
Total	$ 21,439.98

Total fees earned and collected amounted to $23,597.08. Deducting the salaries paid from the earnings of the office leaves surplus fees for the period of $2,157.10. The use of modern methods and elimination of unnecessary clerical help discussed later should increase this surplus.

County Treasurer's Office

Commissions charged to the various funds for the collection of taxes and miscellaneous collections as provided for by law amounted to $29,487.68, all of which was transferred to the ordinary county fund with the exception of $27.67 charged off on account of cancelled tax receipts and rebates.

Salaries paid for the year 1928 were as follows:

Treasurer	$ 3,000.00
Deputies, 4	7,080.00
Clerical assistants, 4	426.00
Total	$10,506.00

Consolidation with the assessor's office would result in considerable savings.

Suggestions for Improvement

Machine Methods Reduce Expenses.—County government in all its phases is today face to face with a new set of conditions born of modern needs. Up-to-date methods must prevail if expenses are to be reduced. By reducing the costs, controlling expenses, and eliminating unnecessary clerical labor, modern business machines contribute to the development of better county management. Larimer County can profit thru the use of modern business machines in the transaction of county business. With modern machines one can get a daily report from practically every department of the county, a report posted up to the previous night's closing that tells exactly where the county stands today.

Old Versus New Methods.—An illustration may be given showing the comparative clerical operations under the present methods[1] and the new mechanical system, in the following tabulation:

TABLE 12. COMPARISON OF PEN-KEPT BOOKKEEPING VERSUS MECHANICAL METHODS

	Operations Performed	Under the Pen-kept Cashbook Systems	Under the Mechanical Bookkeeping Methods
1.	Preparation of voucher	1	1
2.	Posting by automatic posting machine direct to accounts	....	1
3.	Entering voucher on register	1	
4.	Posting from voucher to record	1	
5.	Adding and balancing voucher record	1	
6.	Journalizing voucher record totals	1	
7.	Posting monthly totals voucher record	1	
8.	Entering warrant on cashbook or treasurer's record	1	
9.	Balancing cash book	1	
10.	Posting cash book	1	
11.	Entering or journalizing for funds	1	
12.	Posting to fund accounts	1	
13.	Entering or posting to budget accounts	1	
14.	Adding and balancing budget accounts	1	
15.	Adding and balancing general ledger	1	
16.	Drawing off trial balance	1	
	Total operations	15	2

[1]George Scott, "Coding, vouchering, and centralized purchasing as related to a mechanical accounting system." The American City, Aug. 1929, p. 162.

The above tabulation may not include all of the operations for keeping the old cashbook systems but it represents the principal operations necessary to keep complete accounts.

Under the mechanical system there are only two major bookkeeping operations: (a) Preparation of voucher; and (b) posting the voucher.

Under the old cashbook system the tabulation shows 15 different clerical operations. The tabulation illustrates the economy, simplicity and promptness of information, as the work of posting the voucher automatically closes the books, and the machine eliminates the mental work of adding, subtracting and balancing.

An attempt to improve the present obsolete method of keeping records involves a change in the present state laws which give in detail the manner in which accounts shall be handled. This illustrates why present state laws are hindrances to county commissioners who wish to operate the local government efficiently.

Need for a Modern Accounting System.—To avoid waste in county business, it is necessary to know where and when the leaks occur. To find the leaks there must be some effective means for detecting them, and of knowing their importance when they are found.

The method of accounting used by Larimer County is ill adapted to modern needs. It is practically impossible to obtain detailed information on any expenditure without examining hundreds of individual vouchers. Recently an investigation was made by the county into excessive expenditures for soap, disinfectants and insecticides by the janitor. In order to check up on this particular leak it was necessary to search thru 35,000 vouchers. It was only by accident that the leak was discovered even in this case.

With a good system of accounts, leaks like this would rarely happen. There are many other leaks but the present system of records would never enable one to detect them.

El Paso County records, as an illustration of good accounting, show detailed expenses in the Outside Poor expense for example as follows: Subsistence, clothing, fuel, rent, county physician, county nurse, physicians and surgeons, supplies and drugs, hospital care, burials, taxi and ambulance, nursing and welfare

worker's salary. Other expenditures are shown with the same detail.

Information such as this is very important to taxpayers. The savings in expenditures thru better accounts would more than offset any extra cost of a better system.

No detailed cost or property record of county real estate, buildings, furniture and fixtures, machinery, tools and equipment, livestock, automobiles or office supplies is kept by the county.

An attempt at an inventory was made by the auditor in his report for 1925 which is as follows:

TABLE 13.—VALUE OF BUILDINGS, LAND, ETC., LARIMER COUNTY, JUNE 30, 1925[1]

Courthouse building, grounds and furniture	$ 80,000.00
Dwelling, lot 9, blk. 102, Fort Collins	3,500.00
Lots 5 to 8, blk. 102, Fort Collins	7,500.00
Poor house property in SW sec. 18-7-68	103,000.00
Property in hands of road overseers (estimated)	5,000.00
Lumber and material in yards (estimated)	28,000.00
Machinery and supplies (estimated)	85,000.00
70 acres NE sec. 16-9-69	2,000.00
Garage	15,000.00
Total	$329,000.00

Note that in three of the most important items, the totals were estimated, giving an inventory which is worthless for practical purposes.

No attempt is made by the county highway department to study the cost of operating highway equipment such as motor trucks, tractors, etc. It is impossible to do this since no records of this sort are kept.[2] County commissioners are unable to tell from the records kept just what it costs to operate equipment of any kind. Some of the road equipment is obsolete. A modern system of accounting would indicate when and where savings could be made under such conditions with little if any additional expense.

While modern accountancy is no cure-all for all evils, it is a stop-cock for many wastes. Its orderly application of system and method of management, the assurance of its detailed audit, the guide of its budget, its light on costs, and, above all, the security of its control, will lessen every day the greater wastes due to lack of accounts.

[1]Auditor's Report.

[2]A system of records which will enable the county to learn the cost of operating highway equipment has recently been installed. (Jan. 30, 1930.)

Machining of Tax Records and Bills.—No man should do what a machine can do better and quicker. Every year the county treasurer collects city and county school taxes from all property owners in Larimer County. Every year he goes thru the same process for the collection of taxes. This means a lot of record keeping.

Each parcel of land must be entered annually upon the tax roll, with a description as to location, dimensions, assessed valuation and the owner. One or more tax bills also must be prepared every year. In 90 percent of these parcels there is no change from year to year in any of the information recorded. The clerical detail is thus largely a routine re-copying from year to year.

Machines Eliminate Unnecessary Clerical Help.—Machines can be installed to do the vast clerical work involved in the assessing of property and billing of taxes every year. A complete set of addressing, tax-extending and tax-billing machines and equipment necessary for all the county offices involved can be set up in a central office. It is estimated that at least one-third of the clerical help can be eliminated with considerable saving to the county.

Weld County installed the machine method of handling tax records in 1926. The assessor states that under the old long-hand system it required 8 clerks employed for 4 weeks to merely write the names and descriptions of property. Under the machine system it takes 2 persons 4 days.

Under the old long-hand system it took 8 persons 6 weeks, often working nights, to extend and balance the tax rolls. Numerous difficulties were had in balancing the books under the old system, resulting in many errors. The old system required 2 people for 2 weeks to proofread the records after they had been copied in long-hand. Under the new system it requires 3 people 26 days to complete the valuations and a similar period to extend the taxes.

Errors Practically Eliminated.—When this work is complete the records are automatically checked and balanced. In fact, under the new system only 3 mistakes have been discovered in a period of 3 years.

The assessor states that this year they have 26,218 tax schedules. He stated that about 20,000 of these have land descriptions, 90 percent of which do not change from year to year.

The treasurer's office formerly required 4 typists and 8 extra workers to prepare the tax statements. Under the new method one machine and operator handles all of it.

Machines Have Paid for Themselves.—The machines in Weld County have already paid for themselves. They have saved money and time, speeded up operations, simplified record writing and insured accuracy.

Weld County has about 135 school districts, while Larimer County has 46. The assessments are all kept separate for each school district so on this basis one-third of the equipment used in Weld County should handle the work in Larimer County.

Photographic Recording Would Save Money for Taxpayers.—The report of the county clerk and recorder shows that $16,323.65 was spent for clerical help in issuing auto licenses, certificates of titles, and for recording legal instruments. See Table 11.

The salary statements show that five persons were employed to record, proofread and index legal instruments.

Photographic recording would save the county between $4,000 and $5,000 a year. In addition to a financial saving there would be a saving in time and space and the elimination of annoyance due to inaccuracies of hand copying. The services of three or four clerks could be dispensed with. A modern machine with a life of at least 30 years can be installed for approximately $4,000 which will pay for itself the first year.

Advantages of Photostat Process.—The photostat process for recording written documents is both cheaper and better than methods now in general use and should be thoroly investigated by all county officials. Five distinct advantages are claimed:

1. Photostat copies of any document can be made and are ready for use in a few minutes.
2. Photostat recording is economical, costing less per folio than any other known process.
3. Photostat prints are accurate, the print being a facsimile of the original document.
4. Photostat prints are permanent; they will not fade and will last as long as the paper base.
5. Interlineations and deletions cannot be made in photostat prints without being detected.

Summing up in brief form, we might say they have speed, economy, accuracy and permanency. Furthermore, they are legal and fraud proof.

Many local governments thruout the country are adopting the photostatic method of recording land instruments, wills, and similar documents filed for permanent record in state, county and city offices. Some of the counties in Colorado which have adopted this method are: Weld, Adams, Arapahoe, Denver and Las Animas.

Opposition to change is a human trait, however. There always seem to be ready reasons why new methods, new processes, new plans will not be practical. But how many business men would return to the office methods of our grandfathers such as we find in our counties? Yet in our counties today long-hand methods are used in heading tax statements, writing letters, filling in tax-collection forms, listing tax roll forms, writing checks and doing countless other daily tasks. Machines are doing this work for thousands of business concerns and a few progressive counties 10 to 50 times faster, with less expense and, what is often most important of all, without possibility of error.

Expenditures for Printing and Newspaper Advertising Excessive

Expenditures for newspaper advertising seem excessive when compared with similar expenditures in other counties.[1] Table 14 gives the approximate amount spent in 1928 for printing of election material and legal notices.

TABLE 14.—PRINTING AND ADVERTISING EXPENDITURES, 1928

Item	Amount
Delinquent tax notice	$5,211.60
Treasurer's notices	288.37
Election notices	801.14
Election ballots	2,194.30
Notice of commissioners' proceedings	1,389.06
School notices	25.18
County clerk's notices	82.32
	$9,991.97

Greater publicity of county affairs advocated in other portions of this report does not necessarily mean added expense as some would have us believe.

At present newspapers carry statements of the county piecemeal. Instead of giving the entire exhibit in one issue, a dozen issues or so carry the story of county finances. To get the whole report it is necessary to clip from week to week, file the fragments carefully away, and finally assemble all the parts for study

[1]Steps have been taken by the county commissioners to reduce the cost of printing.

—a tax upon the attention to which the average citizen is not equal. As a result the most alert taxpayer throws up his hands in despair. It is a good way of confusing the public mind, but it is the common way of showing county finances.

But the money of the taxpayers will be wasted in this fashion for many years to come unless intelligent citizenship demands a businesslike statement of county finances.

In Larimer County there is no proper assembling of assets, indebtedness, receipts and expenditures for the various purposes of county business. The present exhibits lack a classification of accounts, and therefore nobody can tell exactly how much is spent for this or that purpose—say on paupers, the total number or the per capita cost; or on highways, the miles built, the average cost per mile of the different types of road, the per-capita cost of labor or road equipment.

As a result the average citizen knows little or nothing about county finances, about the tax list and the amazing inequalities it discloses everywhere; about what the county revenues are spent for, and whether they are spent wisely or unwisely, effectively or wastefully.

What the county needs is a really worthwhile kind of financial exhibit by the board of county commissioners—an orderly affair, as it ought to be for the average reader. It should be so simple and compact that the average taxpayer can read it and get some sense out of it.

He should be able to see the receipts in detail and in lump sums. Under proper headings he should be able to find just how much was spent for the various purposes, to whom the county money was paid and for what—the total expense of: Paupers, the hospital, care and feeding of prisoners, bridges, road building and repairs by districts, equipment and materials purchased, interest paid, county office commissions and fees, the cost of salaries, and so on. He should see at a glance what the bonded and floating indebtedness of the county is.

County bookkeeping and reporting ought to be simple and uniform, and then there would be some basis for comparing one county with another in the details of county business.

Wherever the business end of county affairs has come under strict review and pitiless publicity, amazing inefficiencies have been disclosed.

Jail Expenses Can Be Reduced

At present the county pays the sheriff 40 cents per meal for 2 meals a day for each prisoner. The county could probably save

by furnishing food and having the sheriff serve it. The cost per meal for a superior quality of food at the hospital is about 20 cents per meal which should be approximately the cost for feeding prisoners per meal at the jail. This would also remove an incentive to keep the jail full of prisoners. The number of prisoners[1] in Larimer county jail was as follows:

1925	264	1927	273
1926	251	1928	237

Interest on Public Deposits

Interest on daily bank balances for the year 1928 amounted to $5,573.40. Larimer County should invite competitive bids for public bank deposits in order to secure fair and adequate interest rates. The experience of those communities has been excellent where competition has been the method employed to secure a more favorable return on the public's money. At present the county obtains only 2 percent, the minimum required by law. It is recommended that an earnest attempt be made to secure a larger return. The above recommendation applies equally as well to school funds. All funds should be deposited promptly to secure interest on all money.

Summary

Expenditures in Larimer County have risen rapidly the last 4 years with expenditures exceeding revenues every year until a large floating indebtedness has been created.

Every department of the county has shown an increase, with the expenditures for roads, schools and general government showing the largest increases.

The county expended more than $1,700,000 in 1928. The expenditures in 1924 for the same purposes were $1,460,000.

General governmental expenditures could be reduced by consolidating several departments under one head and by the introduction of modern business methods in the different offices. Some of these changes would require that the state constitution be amended before they could be adopted.

Many leaks go undiscovered because of the inadequate and out-of-date system of accounting used at present.

The assessor could reduce his clerical labor one-third by the introduction of modern machine methods in the handling of tax records.

The county clerk and recorder could reduce clerical labor by installing labor-saving devices and a modern photostat machine for recording legal instruments.

[1]Colorado Yearbook, 1928-1929.

Expenditures for newspaper advertising seem excessive when compared with those in other counties.

The cost per day of feeding prisoners looks excessive.

Greater publicity of county financial affairs is advocated.

ROADS AND HIGHWAYS

Increasing Importance of Highways.—Demands for highway service have been increasing rapidly in Larimer County during the past 10 years. Its registered motor vehicles have increased from 4,600 in 1919 to 11,693 in 1929. In the latter year there was one motor vehicle for each 2.5 persons.

The number of motor vehicles (passenger cars and trucks) in use per unit of population has been consistently greater in Larimer County and in Colorado in recent years than in the United States as a whole. The number per 100 people has increased steadily in Larimer County from 19.6 in 1920 to 39.3 in 1929; in Colorado from 11.9 in 1920 to 28.6 in 1929; and in the United States from 7.6 in 1920 to 22.2 in 1929. The figures for these and intervening years are given in Table 15.

TABLE 15.—RELATION OF THE NUMBER OF MOTOR VEHICLES IN USE TO THE POPULATION, LARIMER COUNTY, COLORADO, AND THE UNITED STATES

Year	Number in Use per 100 People			Number of People per Vehicle		
	Larimer County	Colorado	United States	Larimer County	Colorado	United States
1920	19.6	11.9	7.6	5.1	8.4	13.2
1921	24.4	13.5	8.7	4.1	7.4	11.5
1922	23.2	14.6	9.6	4.3	6.8	10.4
1923	25.8	16.4	11.4	3.9	6.1	8.7
1924	31.2	18.4	13.4	3.2	5.4	7.5
1925	33.7	19.7	14.6	3.0	5.1	6.8
1926	34.3	21.0	16.2	2.9	4.8	6.2
1927	37.5	21.9	17.3	2.7	4.6	5.8
1928	37.6	26.2	20.6	2.6	3.8	4.9
1929	39.3	28.6	22.2	2.5	3.5	4.8

The map of page 43 shows the location and type of roads in each road district.

The mileage of different kinds of roads is given in Table 16. It shows that 3.8 percent of the total mileage was federal aid, 11.9 percent state highway, and 84.3 percent county road.

Increased Expenditures for Highways.—Highways account for a major portion of the increase in county taxes and floating debt, but nothing in the signs of the times indicates any recession in highway activity. As motor vehicles increase in number the people will demand more, better and wider highways.

TABLE 16.—MILEAGE AND CHARACTER OF ROADS IN LARIMER COUNTY

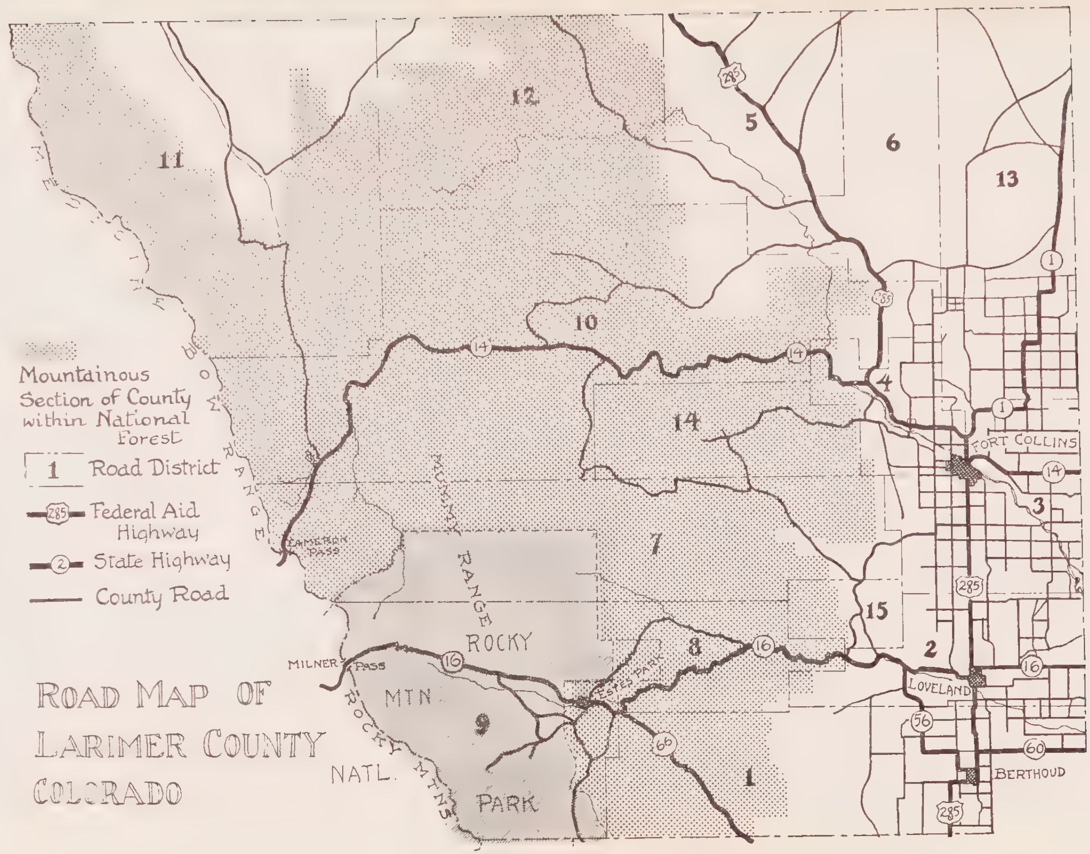
Highway No.	Location	Character	Mileage	Expenditure per Mile in 1928[1] by Larimer Co.
Federal Aid				
285	Denver-Laramie	22.6 mi. paved 38.4 mi. gravel	61	
State Highway				
14	Poudre Canon	gravel	69	$611
16	Big Thompson Canon	gravel	45	884
66	Estes Park-Lyons	gravel	12	435
1	Fort Collins-Cheyenne	gravel	41	362
60	East Campion	gravel	3	10
56	Berthoud Cutoff	gravel	10	16
7	South St. Vrain	gravel	10	-----
	Total State Highway		190	
	County roads		1,350	$165
	Grand total		1,601	

An analysis of the road and bridge receipts and expenditures for 1928 shows that a total of $247,947.18 was collected from different sources. Two-thirds of the receipts came from local property taxation. The rest came from gasoline tax, motor vehicle licenses, state highway, fines, Forest Service remittances and miscellaneous sources. Table 17.

A total of $1,802,970 was spent on roads in Larimer County in the past 5 years. This is an average of $360,594 per year. The warrants issued for road and bridge expenditures in 1928 amounted to $407,620.62. This amount was distributed as follows: County roads, $167,487.06; state highways, $78,178.79; special road projects, $10,447.88; and general road expense including garage, trucks, machinery and supplies, $151,506.89. These large expenditures left a deficit at the end of the year amounting to $159,673.44. Table 17.

The amount of money that was spent on each road district, state highway and project is shown in Table 18. In this table the general road fund is distributed according to the method used by the highway department. This shows that $65,706 in the road fund was undistributed to the different types of road. With a good system of accounts this overhead would be distributed to the various roads either on a mileage basis or on a volume-of-expenditures basis.

[1]Excluding undistributed general road expenditures of $60,306.43. The expenditures include capital outlay in addition to operating expense.



Mountainous Section of County within National Forest
1 Road District
285 Federal Aid Highway
2 State Highway
County Road
ROAD MAP OF LARIMER COUNTY COLORADO
FORT COLLINS
LOVELAND
BERTHOUD
ESTES PARK
MILNER PASS
CAMERON PASS
MUMMY RANGE
ROCKY MTN NATL. PARK
ROCKY MTNS
MEDICINE BOW RANGE

Farmers are taxed to build and maintain the Big Thompson road leading to the Rocky Mountain National Park which is used largely by tourists and city dwellers in Colorado

TABLE 17.—SUMMARY OF ROAD RECEIPTS AND EXPENDITURES, LARIMER COUNTY, 1928[1]

Road and Bridge Revenue:	Amount
Taxes, current property	$163,599.20
Taxes, delinquent	1,162.82
Gasoline tax	27,000.74
Motor vehicle licenses	31,310.18
State highway maintenance	14,882.65
Fines	1,170.08
Forest reserve	6,179.79
Miscellaneous	2,641.72
Total receipts	$247,947.18
Expenditures:	
County road districts	$167,487.06
State highways	78,178.79
Special road projects	10,447.88
General road (truck labor, garage) expense, road machinery, and supplies	151,506.89
Total expenditures	$407,620.62
Deficit, 1928	$159,673.44

Table 18 shows that of the total expenditures, 54.5 percent was expended on county roads; 26.1 percent on state highways; 16.1 percent on undistributed general road expenditures for supervision, machinery and supplies; and 3.3 percent on special projects.

Expenditures show that 26.1 percent of the funds were spent on state highways which only comprise 11.9 percent of the total road mileage in the county. County roads comprise 84.3 percent of the mileage and only receive 54.5 percent of the funds.

Cost Per Mile High on Mountain Roads.—The number of miles in each district was estimated by the county engineer since no record is kept by the county. Using an estimate of 1,350 miles of county highway gives an average expense of $165 per mile for 1928. The expenditures on the Fort Collins-Cheyenne road amounted to $362 per mile, the Poudre Canon road $611 per mile, the Loveland-Greeley-Estes Park road $884 per mile, the Berthoud cut-off $16 per mile, the East Campion road $10 per mile, and the Lyons-Estes Park road $435 per mile.

Expenditures on the mountain roads are extremely heavy in spite of the fact that they do not include $65,706 of undistributed general road fund.

Distribution of Expenditures According to Type of Work Performed.—The amount spent for maintenance, surfacing, bridges, earthwork, rockwork, drains and culverts, supervision, and stock (supplies, truck use, lumber, pipe, etc., distributed from the general road expense) is shown in Table 19.

[1]Auditor's Report and records of county commissioners' office.

Larimer County spent $611 per mile on this Cache la Poudre canon road in 1928, which is used largely by tourists and city residents

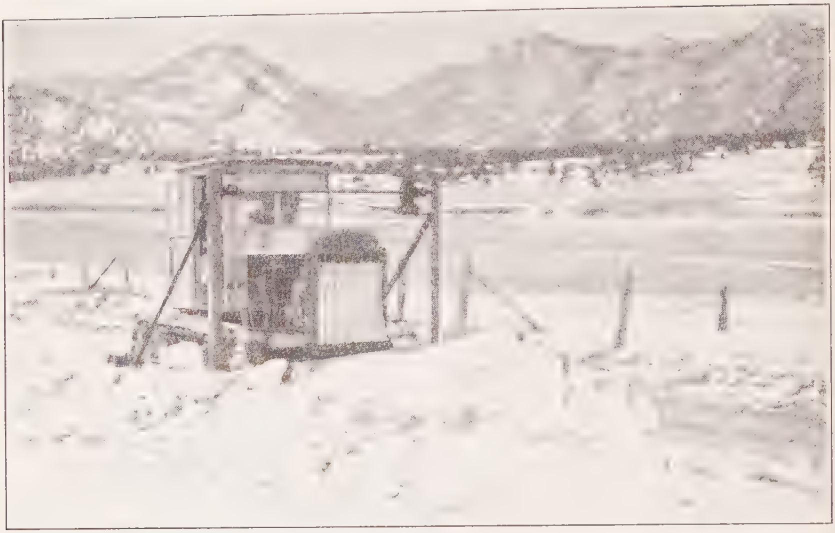
TABLE 18.—ROAD AND BRIDGE EXPENDITURES DISTRIBUTED TO DISTRICTS, STATE HIGHWAYS AND SPECIAL PROJECTS, LARIMER COUNTY, 1928[1]

Purpose of Expenditure	Warrants Issued Directly	Stock Charged from General Roads	Total Road Expense	Percentage Distribution
County road district:				
1	$ 18,451.72	$ 8,685.15	$ 27,136.87	
2	23,027.49	13,559.78	36,587.27	
3	43,134.01	14,818.84	57,952.85	
4	16,870.12	1,631.34	18,501.46	
5	629.65	20.20	649.85	
7	7,128.81	995.90	8,124.71	
8	2,139.73	257.48	2,397.21	
9	15,521.13	1,502.72	17,023.85	
10	6,574.46	2,212.51	8,786.97	
11	3,881.76	66.40	3,948.16	
12	2,894.22	168.05	3,062.27	
13	24,548.29	10,893.85	35,442.14	
14	2,685.67	26.95	2,712.62	
Total county roads	$167,487.06	$ 54,839.17	$222,326.23	54.5
State highway number:				
1	$ 9,159.46	$ 5,683.13	$ 14,842.59	
14	29,798.94	12,344.69	42,143.63	
16	30,541.66	9,216.76	39,758.42	
56	165.81	....	165.81	
60	32.00	....	32.00	
66	4,474.79	750.75	5,225.54	
123	4,006.13	53.45	4,059.58	
Total state highway	$ 78,178.79	$ 28,048.78	$106,227.57	26.1
Special road projects	$ 10,447.88	$ 2,912.51	$ 13,360.39	3.3
General road expenditures undistributed	....	$ 65,706.43	$ 65,706.43	16.1
Grand total	$256,113.73	$151,506.89	$407,620.62	100.0

TABLE 19.—PERCENTAGE DISTRIBUTION OF EXPENDITURES ON ROADS AND BRIDGES, LARIMER COUNTY, 1928[1]

	Percentage
Maintenance and dragging	23.3
Surfacing	30.8
Bridges	7.6
Earthwork	1.4
Rockwork	5.6
Drains and culverts	1.1
Supervision	4.2
Snow removal	1.1
Stock (machinery and supplies)	24.9
	100.0

[1]Records from office of county commissioners. See map for location of districts and highways.



Snow removal on Estes Park highway—a new service demanded by the taxpayers

The items of expense included in the general road expenditures are shown in Table 20.

TABLE 20.—DISTRIBUTION OF GENERAL ROAD EXPENSE, LARIMER COUNTY, 1928[1]

Trucks	$ 19,037.39
Drivers and mechanics	11,214.47
Engineering department	5,556.32
Garage expense	2,498.25
Machinery and supplies	75,122.57
Lumber	10,600.14
Pipe	2,823.21
Gas and oil	14,214.06
Steam shovel	238.57
Right-of-way	2,621.79
Miscellaneous	7,579.22
Total	$151,506.89

A detailed statement of some of the more prominent items of road equipment purchased by the county commissioners is given in Table A in the appendix to give an idea of how money was spent. No records of any kind are kept concerning the cost of operating any of this equipment, and no inventory or stock record is kept to show the final destination of the equipment.[2]

[1]Records from office of county commissioners.
[2]Records were installed in 1929 which now give part of this information.

County Commissioners Divide Responsibility for Roads

Larimer County is divided into 15 road districts under the general supervision and control of three county commissioners. Each of the three commissioners personally oversees the road work in one-third of the county. One commissioner has supervision over road districts 4, 5, 6, 10, 11, 12 and 14; another looks after districts 1, 2, 8, 9 and 15; and the third commissioner has charge of districts 3, 7 and 13.

While this practice has something to commend it and has proved successful in some instances, it produces divided authority, makes patchwork of the roads and is not ordinarily desirable. Would not one full-time administrator be worth more than a dozen part-time commissioners?

The county road supervisor should be a trained road man and a good executive, who is absolutely free from political obligations. He should be selected solely on the basis of merit and, having been appointed, should be given considerable latitude in his actions. He should be permitted to select his own assistants without regard to their political affiliations. So far as possible the supervisor should work in harmony with the county commissioners, departing from their counsel only when his greater technical knowledge convinces him that they are wrong. The commissioners should determine matters of policy and he should execute their orders in the most efficient manner possible.

The county supervisor should provide himself with a complete set of county maps showing the location of all roads by class and type. Other maps should indicate present roads and plans for future construction. The mileage of the different types of roads in the county should be available. Other maps should indicate traffic conditions, traffic counts and other needed information. At present no such maps are available.

The supervisor should also check the delivery of all road supplies and keep a perpetual inventory of road machinery and materials. It should be his duty to verify all payrolls and all other road expenditures.

A county with as much construction to do as this county should employ an experienced road engineer with necessary assistants.

The proper maintenance of roads already built is highly important. Because of poor management counties have often failed to keep up their new roads. This is a mistaken form of economy. It would be better to build fewer miles of new road than to neglect those already built.

The public business of providing highway service for these fast-multiplying automobiles and trucks, thru the development of highway systems, has become an important industry. Successful management of this public industry is fundamentally similar to the management of private business, requiring: (1) Sound analysis of the demand for the product; (2) efficient production methods; and (3) proper financing. At present Larimer County is not meeting all of these requirements.

The development and improvement of a highway system to meet traffic demands within the normal limitations of funds require careful planning over a period of years. Plans must be made at the present time to meet future traffic demands, and improvements must be made so as to provide adequate service thruout the life of the highway or bridge.

The demand for highway service can be measured only by an accurate and comprehensive study of the present traffic, its volume and type, upon which prediction of future traffic must be based.

To meet this purpose the following specific information is needed in Larimer County:

1. The relative importance of the highway systems within the county as a basis for determination of the need for their improvement and the distribution of funds among the systems.

2. Classification of highway routes and sections of routes on the basis of the volume and characteristics of present and expected future traffic, involving: (a) Average, maximum and future total traffic and truck traffic; (b) present and future number of small, medium and large-capacity trucks; (c) present and future maximum loading and frequency of heavy gross loads and wheel loads; (d) present and expected future special traffic movements; and (e) present and future number of foreign (out-of-county) registered cars.

3. Establishment of a plan of highway improvement for a period of several years.

County Should Spend Its Road Money Logically

As a suggestion for the allotment of available money to various classes of roads, the principle may be laid down that each vehicle is entitled to have spent upon the road it travels the prorata share of the highway funds that it supplies by gasoline or other taxes. This principle will call for expenditures to be allotted on the highways according to the traffic. For practical application, the county road system should be divided into groups according to the traffic density, and all road building and maintenance co-ordinated into one plan.

One and one-half million dollars worth of sugar beets were hauled over Larimer County farm-to-market roads in 1928

This grouping naturally calls for a traffic survey of the county, but it is believed that in order to build a highway system adequately and ecomonically, a traffic survey is essential, so that the flow of traffic may be known and properly provided for. A comprehensive traffic survey would naturally classify the roads on a basis of their potential traffic rather than on the actual traffic count prior to improvement. Highway planning of today must be made with traffic requirements of the future in mind. The proportion of the total traffic on each group will give a basis for allotting the highway funds. Such a survey might save years of haphazard planning as well as several thousand dollars to the county's taxpayers.

The Cost of Roads in Larimer County Too High for Local Taxpayers to Bear

A traffic survey of the roads of Larimer County will show that a good share of them are no longer local roads. In nearly every instance our improved roads are a part of some system of highway that extends from one border of the state to the border line on the opposite side of the state, or it is a link in a nation-wide highway.

These roads should be built and maintained as a state-wide proposition and this should be purely a state operation. In addition the state should aid the county in building up a secondary or lateral system of highways.

The support that comes from the state and federal sources should be proportioned to the present use of the highways and should anticipate greater future use especially of our mountain

roads by those outside of the local community. Roads which should receive more aid from state and federal sources are the Big Thompson road, the Lyons-Estes Park road and the Poudre Canon road.[1]

Justice in taxation requires that a part of the burden now borne by farm property in Larimer County to build and maintain these roads should be transferred to other sources of income and that a larger part of the total revenue for this purpose be obtained from taxes levied on larger territorial units.

Present System of Highway Accounts Inadequate

An accurate measure of expenditures for highway purposes in Larimer County is practically impossible because of lack of mileage records of highways in each district and lack of segregation of expenditures on each type of road.

Larimer County has charged all capital outlay expenditures to the operating costs of the year in which the expenditures were made. Under this system of accounting, the county makes expenditures for capital outlay year after year and makes no ledger account of property so accumulated. It is therefore impossible to make comparisons of operating costs from year to year because capital expenditures vary greatly. Much of the work classed as maintenance should in reality be charged to new construction.

Property account records should be kept for each district in order to show true operating costs. It is suggested that the county commissioners of Larimer County study the system of accounting used by El Paso County. The auditor's report for El Paso County for 1928 gives a great deal of information concerning the roads, practically none of which is available in an intelligible form in Larimer County. For example, (1) separate accounts are kept for each truck and tractor, (2) garage expense is segregated and (3) detailed records are kept of all equipment.

Summary of Section on Highways

Road development has reacted to the benefit of the county, and as good roads were extended, transportation and commerce have shown increases. Farm conditions have improved and property values have been enhanced.

The motor registration increased until there was one motor vehicle for each 2.5 persons in 1929 compared with 5.1 in 1920.

[1]On December 3, 1929, in a talk before the Kiwanis Club of Fort Collins, the writer pointed out that it was unfair to ask Larimer County to build and maintain a highway to the Government parks used extensively by tourists and out-of-county residents.
On December 5, 1929, representatives of the Chambers of Commerce of cities of northern Colorado in a joint meeting in Fort Collins took immediate steps to find a way of making the Big Thompson Canon road a 100 percent federal road to the Rocky Mountain National Park.

Larimer County has 1,601 miles in the road system classified as follows: Federal aid, 61 miles; state highway, 190 miles; and county roads, 1,350 miles.

The total highway receipts were $247,947.18 and total expenditures $407,620.62, leaving a deficit of $159,673.44 for 1928.

The expenditure per mile for some of the more important roads in 1928 was as follows: Poudre Canon, $611; Big Thompson, $884; Estes Park-Lyons, $435; Fort Collins-Cheyenne, $362.

The county needs to make a traffic study in order to spend its road money logically, and in order to save years of haphazard planning for the future.

It is suggested that the county commissioners place the entire highway system under the supervision of a capable road supervisor, selected solely on merit, who will be permitted to select his own assistants such as the engineer, district road supervisors and other assistants.[1]

CHARITIES, HOSPITAL AND COUNTY-FARM EXPENDITURES

Outside Poor Relief

Outside poor relief is given to persons who remain in their home rather than in an institution and is authorized primarily where the person requires temporary relief, is sick or disabled thru injury or age, so that he cannot be conveniently cared for at the county home or hospital.

There are many occasions when it is more humane as well as more economical to grant outside aid than to attempt to keep the persons at the county home. This is especially true in the case of old people who have friends or children willing to give them care but who are financially unable to support them, and in the case of dependent widows with minor children.

The average number of cases receiving aid during the year is about 150, increasing to 300 during the winter and early spring.

Expenditures for the poor have risen rapidly and the problem of caring for the poor is becoming increasingly serious. Outside poor expenditures increased from $13,896 in 1924 to $33,138 in 1928, or an increase of 138 percent. Expenditures for 1924 to 1928 are shown in Table 21.

[1]Attention is called to an excellent report on "Road Cost Accounting Plan for Solano County, California," California Taxpayers' Association, Los Angeles, California.

TABLE 21.—OUTSIDE POOR EXPENDITURES IN LARIMER COUNTY, 1924 TO 1928[1] (ON THE BASIS OF WARRANTS ISSUED.)

Year	Amount	Percentage Increase Over 1924
1924	$13,896	..
1925	18,910	36
1926	21,856	57
1927	26,365	90
1928	33,138	138

There are several causes for the increase. The increase in the sugar-beet acreage has brought in a larger number of Mexicans, many of whom become a charge upon the county, especially during the winter season.

In some cases the husband or son who is depended upon to support the family is sent to jail or the state penitentiary and as a result the family becomes dependent upon the county for help. Work of some sort needs to be supplied such prisoners so that they can help support their families. This problem has been recognized by the commissioners, but the solution is extremely difficult.

The tendency is for a case to become a permanent charge upon the county after once receiving help. It seems that a certain type of people does not hesitate to ask the county for aid and it is extremely difficult to eliminate these cases. Primarily it is a problem of good administration and requires that the officer in charge of the poor fund have a complete history of every case seeking aid from the county.

Relief has often been granted to those who have near relatives well able to care for them. The solution to this problem is to find some method of forcing relatives to provide help.

Another abuse that should be corrected is the practice of granting cash payments which are often wasted for unnecessary things instead of the proper food or clothing. The willingness of great numbers to accept cash contributions suggests that their requests for aid are not always deserving. At present the quality of the goods furnished is left to the discretion of the merchant selling them. A ticket or order system calling for a certain definite amount and quality of supplies should replace this system in many instances.

Many non-residents who come to Colorado in order to recover their health have small financial resources and soon require aid from the county.

[1]Auditor's Report.

It is evident that the dispensing of outside poor relief is likely to be accompanied by a great deal of wastefulness unless there is very careful supervision. Each case needs to be thoroly investigated before aid is granted. A case worker who could cooperate with all the welfare organizations in the county and exchange records of all persons receiving aid would help to keep the expense down. The large expenditures justify a full-time trained worker.[1]

A well-planned and ably directed budget would be of considerable assistance in keeping down the expenditures in this department.

A serious attempt should be made to provide employment for the unemployed. A great deal of effort should be made to discover and remove, if possible, the sources of poverty. Taxpayers should cooperate with county officers in solving these problems thru different organizations. A welfare worker should search out and render assistance to those who are likely to become public charges later. Rehabilitation work should be encouraged and an opportunity given to learn a trade where it is needed so that one may become a self-supporting member of society instead of depending upon the county for support.

Larimer County Hospital

Larimer County has an excellent hospital built in 1925 at a cost of approximately $175,000, with a present value of $225,000. It is the only hospital in the county[2] and therefore provides for cases other than charity cases. From 70 to 75 percent of the cases are pay patients, so called to distinguish them from the charity cases. The hospital was built and is supported by the taxpayers. The county home is operated in connection with the hospital so it is therefore difficult to segregate expenses. The practice is to charge all expenses against the hospital and to make certain flat charges against the home in order to show its share of the expense.

The annual expenditures for the hospital and home from 1924 to 1928 are given in Table 22.

TABLE 22.—LARIMER COUNTY HOSPITAL AND HOME EXPENDITURES, 1924-1928[3]

Year	Amount
1924	$15,682
1925	16,376
1926	51,903
1927	65,754
1928	70,091

[1]During 1929 the county provided an official who devotes practically all of his time to the administration of outside relief during the winter months and part time to it during the summer.

[2]Two small private hospitals were recently established in Loveland in 1929 with a bed capacity of 6 beds each.

[3]Auditor's Report.

Altho the foregoing figures indicate a large increase in expense it must be remembered that the net expense to the county did not show such a large increase because the earnings received from pay patients after 1925 offset part of the expense.

The pay patients more than pay their way so far as the operating expense of the institution is concerned. The expense of pay patients as shown in the hospital reports and the auditor's report, however, does not include a charge for interest on investment or make an allowance for depreciation on the building. When these charges are included as part of the total expense the result shows a loss of $3,955.

Rates Charged for Hospital Service.—The problem of providing hospital care to the citizens of Larimer County is largely a question of cost. To the patient, of course, the price charged for hospital care is a matter of extreme importance. The hospital is also concerned in this matter, for no institution can ignore the relation of income to expenditures.

Hospital charges are of two sorts: First, the daily or basic rate for room or for bed, including food, nursing and such services as the hospital provides under general care; second, extra or special-service charges.

The basic daily rates charged for beds in various types of accommodations are shown in Table 22a.

TABLE 22A.—THE RATES CHARGED FOR HOSPITAL SERVICES FOR PAY PATIENTS, LARIMER COUNTY HOSPITAL, JULY 1, 1929

Private rooms	$ 5.00 per day
Two-bed rooms, each bed	4.00 " "
Wards	2.50 " "
Operating room	15.00 major
Operating room	7.50 minor
X-Rays as per schedule, State Compensation Insurance Fund.	
Casts—body	7.50 each
Casts—limb	5.00 "
Ambulance	.25 per mile
No charge less than $5.00	
Maternity cases:	
Ward beds	$ 4.00 per day
Two-bed rooms	5.25 " "
Private rooms	6.25 " "

This includes delivery room charges, care of baby and use of baby clothes.
Operating room charges include ether, dressings, sutures, nurses, etc.
X-ray pictures include up to three pictures.

The earnings from pay patients and expenses for the year 1928 were as follows:

Earnings		$41,594.38
Operating expenses	$35,302.80	
Accounts charged off	2,161.09	37,463.89
Surplus earnings over operating expense		$ 4,130.49

The earnings of pay patients in 1927 was $36,135 and the operating expense $33,370.

The cost to the county for hospital care of county charity patients for 1928, taken from the auditor's report, is as follows:

Operating expense county patients		$16,078.63
Less		
Collections	$ 685.90	
Surplus earnings pay patients	4,130.49	4,816.39
		$11,262.24

The average number of pay patients per day was 26 and county patients 11, a total of 37.

In 1928, 70 percent of the cases were pay patients. Seventy percent of the total cost, including interest on investment and depreciation, amounted to $45,549. The total earnings from pay patients amounted to $41,594, leaving a deficit of $3,955 to be paid by taxpayers. An increase of approximately 10 percent[1] in rates would cover the actual cost, including interest and depreciation, of caring for pay patients and take care of many accounts which are charged off annually because of non-payment by pay patients.

The other alternative is to reduce costs thru better management or by increasing the bed capacity of the hospital so as to take advantage of a reduction in cost due to a lower overhead cost per patient. The present heating plant and kitchen will take care of another wing addition. The hospital was built in the first place to serve the people and to give as many people as possible good

[1]An increase of $1.00 a day in rates charged at the Larimer County Hospital was approved, effective Oct. 15, 1929, since this section was written. The new rates are as follows:

		Percentage Increase
Private rooms	$ 6.00 per day	20
Two-bed rooms	5.00 " "	25
Ward beds	3.50 " "	10
Operating room	15.00 major	none
Operating room	7.50 minor	none
Maternity cases:		
Private room	7.25 per day	16
Two-bed room	6.25 " "	19
Ward beds	5.00 " "	25
Babies under 1 year	3.50 " "	
Contagious hospital:		
Ward beds	6.00 per day	
Special nurse	8.00 " "	
Fees for routine laboratory tests:		
Obstetrical case	1.00	
Tonsil case	1.00	
Medical case	3.50	
Surgical case	5.00	

The 1929 auditor's report shows surplus earnings of only $1,463.49 or $2,667 less than in 1928, when the low rates were in effect.

hospital service at a low cost. It would probably be a good investment to enlarge the present hospital and also the home if some practical method can be found to finance the cost of building the addition.

The county as a whole ranks rather low in hospital facilities when ranked on the basis of hospital beds. The average for the United States in 1928 was one hospital bed for every 134 people.[1] The average for Larimer County in 1928 was one bed for 744 people. This indicates that the county can stand a considerable increase in hospital facilities.

According to the superintendent of the hospital the present institution is overcrowded. The present capacity of the hospital is 40 beds. The hospital does not have sufficient bed capacity so that any particular section may be set aside for any special class of cases. Hence many patients who are able to pay their hospital expense must of necessity be placed in the ward at the minimum rate, at which rate the county is losing at least $1.00 per day.

The following statement gives the hospital operating cost per patient per day for the last 4 years.

TABLE 23.—HOSPITAL OPERATING COST PER PATIENT PER DAY, 1926 TO 1929[2]

	1926	1927	1928	1929
Average number of patients per day	25	34	37	40
Average operating cost per patient	$3.58	$3.55	$3.80	$3.84

The cost of meals ranges from 18 to 24 cents per meal.

Hospital service is expensive, and developments in medical science and hospital management may add new elements of cost. It is possible, by increased efficiency of administration, to reduce costs somewhat. It is also possible to equalize the burden of hospital costs or to lessen their impact upon individual patients by readjusting the services, making changes in structure and administration in order to provide facilities better adapted to the needs of patients of moderate means.

Table 24 gives the hospital earnings and expense in detail for 1928 and per institutional day.

Table 24 shows that the total expense, including interest on investment and depreciation supplied by the writer, amounted to $65,070.43. The total earnings from pay and county patients cred-

[1]The committee on the cost of medical care, "Medical Facilities in the United States," Washington, D. C., 1929.

[2]Auditor's Report.

TABLE 24.—COUNTY HOSPITAL EARNINGS AND EXPENSE, 1928[1]

		Cost and Earnings per Institutional Day
Earnings:		
Hospital service	$42,639.50	$3.15
Operating room	7,239.50	.53
X-Ray	1,089.50	
Board special nurses	842.30	
Ambulance	706.00	
Drugs, dressings, etc.	413.77	.32
Contagious ward	1,077.50	
Zoalite	177.00	
Splints and casts	99.00	
	$54,284.07	$4.00
Operating expense:		
Salaries—		
Nurses	$16,358.41	$1.21
Operating room	1,684.26	.13
Administration	1,200.00	.09
Labor	2,049.48	.15
Office	599.12	.04
	$21,891.27	$1.62
Expenses—		
Operating room	$ 797.66	.06
X-Ray	168.53	.01
Repairs	1,076.50	.08
Drugs, medical supplies	2,327.51	.17
Telegraph and telephone	323.06	.02
Light, heat and power	3,736.49	.27
Linen	612.66	.05
Food	13,119.95	.97
Laundry	4,644.68	.34
Water	82.57	.01
Office	436.42	.03
Household supplies	468.27	.04
Ambulance	69.88	.01
Printing and stationery	262.60	.02
Contagious ward	893.05	.06
Nurses' cottage	721.32	.05
Residence	203.04	.01
Grounds	93.20	.01
Collection expense	99.18	.01
	$30,136.57	$2.22
Total operating expense	$52,027.84	$3.84
Accounts charged off	$ 2,161.09	.16
Interest on bonds	7,881.50	.58
Depreciation on buildings	3,000.00	.22
Total expense	$65,070.43	$4.80
Deficit	$10,846.36	

[1]Cost per institutional day, interest and depreciation calculated by the writer; other figures from auditor's report.

ited to the hospital were $54,284.07, leaving a deficit of $10,-846.36. If interest and depreciation are excluded from the above figures the result shows that earnings practically offset expenses.

The last column in the table shows the institutional cost per day or the cost of 1 patient for 1 day. There is 4 cents difference between the writer's operating cost figure and that reported by the auditor, due to the method of calculating the cost. The total cost amounted to $4.80 per patient, including all charges. The cost of nursing amounted to $1.21 per patient; medical supplies amounted to 17 cents; and the cost of food 97 cents per day.

It is recommended that a careful study be made of the needs of the hospital with the view of ascertaining the advisability of having a county central purchasing department handle all the purchasing requirements of the hospital, in order to bring about the greatest efficiency and savings to the taxpayer.

It seems reasonable to believe that costs could be reduced if the superintendent of the hospital could be selected from men trained for hospital work rather than for some business or profession, even if the county had to pay a higher salary. The hospital superintendent should be selected on a merit basis only, regardless of his political affiliations.

County Home.—The operating expense of the home for the period was $12,147.37. Deducting the cash receipts, $282.70, leaves a net expense of $11,864.31.

The average number of inmates was 23.5 and the average cost per inmate per day was $1.38.

COUNTY HOME EXPENSE

Operating expense:	
Salaries	$ 2,501.92
Clothing	113.62
Tobacco	167.84
Repairs	101.45
Medical supplies	38.24
Telephone	55.00
Light and heat	1,490.68
Food	6,456.53
Laundry	438.82
Water	81.12
Barber	131.00
Household supplies	227.57
Residence	193.34
Grounds	90.35
Miscellaneous	59.89
	$12,147.37
Collections	$ 282.70

Poor Farm.—The receipts from sales together with the farm products used in the hospital amounted to $3,887.25. The operating expense was $3,233.86, leaving a surplus for the year of $653.39.

COUNTY POOR FARM: EARNINGS AND OPERATING EXPENSE, 1928

Sales:	
Calves	$ 132.10
Milk	1,613.40
Hogs	436.26
Chickens	305.49
Eggs	491.05
Apples	469.60
Produce	12.10
Crop rents	427.25
Total	$3,887.25
Operating expense:	
Salaries	$1,284.05
Cow feed	705.70
Chickens and chicken feed	383.43
1928 chicks	300.86
Hogs and hog feed	134.65
Fruits and produce	168.67
Repairs	37.01
Water	24.71
Tools	42.83
Truck	41.40
Calves	3.35
Miscellaneous	106.20
Total	$3,232.86
Surplus before interest or depreciation charges	$ 653.39

Summary

Expenditures for the outside poor have risen 138 percent since 1924 and the problem has become serious.

It would probably be a good investment to enlarge the present hospital and hire a superintendent trained in hospital work in order to reduce the costs and relieve the present overcrowded condition.

The county ranks rather low in hospital facilities when ranked on the basis of persons per hospital bed.

The operating cost per patient per day amounted to $3.84 while the total cost, including interest and depreciation, was $4.80 in 1928.

Approximately 70 to 75 percent of the patients are pay patients.

The pay patients more than pay the operating costs, but show a small loss when depreciation and interest on investment are included.

The county commissioners recently raised the rates from 20 to 40 percent on pay patients, with the idea of increasing the returns from pay patients.

Returns from pay patients show a decrease in surplus earnings for 1929 due to the present high rates, indicating that present rates are too high.

LARIMER COUNTY INDEBTEDNESS

Bonded Indebtedness

Property owners of Larimer County faced a bonded indebtedness on January 1, 1929, of $4,292,810 in county, school district and municipal bonds, or an average of $144 for every man, woman and child in the county.

The bonded indebtedness in Colorado on January 1 was $107,783,076, or an average of approximately $100 per capita. Figures for other counties compared with Larimer County are as follows:

TABLE 25.—COMPARISON OF BONDED INDEBTEDNESS IN FOUR COUNTIES IN COLORADO, JANUARY 1, 1929[1]

Kind of Indebtedness	Larimer	Pueblo	El Paso	Weld
County general	$ 175,000	$ 75,000	$ none	$ none
School district	1,154,300	1,636,300	1,668,500	2,774,400
General municipal	2,207,000	635,000	4,092,000	1,150,000
Special municipal	756,510	3,631,000	364,100	245,550
Total	$4,292,810	$5,977,300	$6,124,600	$4,169,950

Table 26 gives the bonded indebtedness of Larimer County in detail, showing the amounts to be repaid for each dollar borrowed thru the levying of taxes.

Ultimate Cost of Bonds Should Be Considered.—A study of the bonded indebtedness of the county and school districts of Larimer County shows that there is a need for a broader understanding of the methods of financing school and county indebtedness. If the taxpayers of Larimer County realized, for example, that on the total of all county bonds there must be repaid $2.12 for each dollar borrowed and on the total of all school district bonds there must be paid $2.15 for each dollar borrowed, more attention would be given to this important subject and fewer bonds would be voted by the taxpayers who are directly responsible for the bonded indebtedness. The amounts to be repaid for each dollar borrowed thru the issuing of bonds should receive the attention of all taxpayers, as these figures show where a considerable portion of the county and district funds are being expended. Table 26 shows that the amount which must be repaid for each dollar borrowed varies from $1.28 as a minimum to $2.92 as a maximum on the 36 different bond issues.

[1]State Board of Immigration, report 1928-1929.

How Interest Payments Can Be Reduced.—Taxpayers wonder how these heavy payments can be avoided. In many cases interest payments could have been reduced or avoided: (1) By taking care of the expenditures thru a slightly higher tax rate; (2) the cost could have been reduced by issuing serial bonds at reasonable rates with the redemption period starting within 2 years; (3) in other cases the bonds could have been provided with callable dates and redeemed during periods of prosperity: (4) bonds should be issued only in cases of unusual expenditures where this method of financing is shown to be desirable; (5) the school districts and county should, as far as is consistent, adopt the pay-as-you-go plan; (6) each proposed bond issue should be carefully considered and studied as one means of financing, and it should be compared with all other practical methods.

First of all, school districts and counties must know what qualities or features they need when issuing bonds. It is surprising how few districts give much thought to what kind of bonds they should issue. To issue bonds that really fit the individual needs of the county and school districts there must first be a searching analysis to determine what these needs are. For instance, the several terms, interest rates, the cost of the bond issue and the final cost to the taxpayers. Often it will pay school districts to defer action for uncertain changes in the bond market. Prices may or may not go lower or higher as the case may be. It might pay to issue short-term bonds with the idea of refunding the issue when conditions are more favorable.

Small Bond Issues Should Be Avoided.—Small bond issues which are for less than $5,000 should be avoided, if possible, for the cost of legal opinion, election, printing, advertising, etc., is an added cost out of all proportion to the size of the loan. In Larimer County there were 7 small bond issues outstanding April 1, 1929. The interest rates are higher than the average on these issues and the amounts to be repaid for each dollar borrowed are much higher. Timnath, district 21, for example, issued bonds for $2,500 at 6 percent running for 40 years which will cost the taxpayers of that district $2.92 for each dollar borrowed or $4,800 in interest alone. The improvements for which this bond issue was made, passed out of existence 20 years before the time came for redemption. Such small issues as these are certainly questionable methods of finance.

That the term of the bond should be confined to the life of the improvement is elementary. The life of the average bond should not exceed 20 years. Of course the principle has been much abused in practice as in the case cited.

TABLE 26. THE BONDED INDEBTEDNESS OF LARIMER COUNTY AND SCHOOL DISTRICTS. THE AMOUNT TO BE REPAID FOR EACH DOLLAR BORROWED THRU THE LEVYING OF TAXES

Location	School District No.	Date of Issue	Amount of Bonds Issued	Amount of Bonds Retired	Amount Outstanding April 1, 1929	Date Last Bond is Due	Rate of Interest	Number Years Simple Interest	Amount Simple Interest	Number Years Serial Interest	Amount Serial Interest	Total Simple and Serial Interest	Amount Repaid On Each Dollar Borrowed	Optional Date
Loveland	2	1925	$ 90,000	$27,000	$ 63,000	1935	4	....	....	10	$ 79,200	$ 79,200	$1.88	serial
Mt. View	3	1919	14,000	....	14,000	1939	5	20	$ 14,000	....	....	14,000	2.00	1929
Fort Collins	5	1917	55,000	19,000	36,000	1937	5	20	55,000			55,000	2.00	1927
" "	5	1918	20,000	....	20,000	1938	5	20	20,000	....	....	20,000	2.00	1928
" "	5	1921	18,000	....	18,000	1951	5.5	30	29,700	....	....	29,700	2.65	1933
" "	5	1921	110,000	....	110,000	1951	5.75	30	189,750	....	....	189,750	2.72	1932
" "	5	1923	68,000	....	68,000	1953	4.75	30	96,900	....	....	96,900	2.42	1934
" "	5	1924	130,000	....	130,000	1954	4.5	30	175,500	....	....	175,500	2.35	1939
" "	5	1924	200,000	....	200,000	1953	4.5	10	90,000	19	85,500	175,500	1.88	serial
Berthoud	13	1920	85,000	8,000	77,000	1950	5	4	17,000	26	64,800	81,800	1.96	serial
Boxelder	15	1919	20,000	....	20,000	1939	5	20	20,000	....	....	20,000	2.00	1929
Timnath	21	1909	2,500	500	2,000	1949	6	40	4,800	....	....	4,800	2.92	1929
Old Berthoud	22	1914	2,000	....	2,000	1934	6	20	2,400	....	....	2,400	2.20	none
Red Rock	23	1916	4,000	....	4,000	1936	5	20	4,000	....	....	4,000	2.00	1926
Estes Park	30	1915	20,000	....	20,000	1945	6	30	36,000	....	....	36,000	2.80	1930
" "	30	1925	71,000	....	71,000	1945	4.75	20	67,450	....	....	67,450	1.95	1935
Wellington	34	1916	28,000	....	28,000	1946	5	30	42,000	....	....	42,000	2.50	1931
"	34	1920	7,000	....	7,000	1940	6	20	8,400	....	....	8,400	2.20	1930
"	34	1924	4,500	....	4,500	1934	5.5	10	2,475	....	....	2,475	1.55	none
"	34	1925	61,000	....	61,000	1955	4.75	16	46,360	14	20,613	66,973	2.10	serial
"	35	1921	15,000	....	15,000	1941	6	20	18,000	....	....	18,000	2.20	1931

TABLE 26.—THE BONDED INDEBTEDNESS OF LARIMER COUNTY AND SCHOOL DISTRICTS. THE AMOUNT TO BE REPAID FOR EACH DOLLAR BORROWED THRU THE LEVYING OF TAXES—(Continued)

Location	School District No.	Date of Issue	Amount of Bonds Issued	Amount of Bonds Retired	Amount Outstanding April 1, 1929	Date Last Bond is Due	Rate of Interest	Number Years Simple Interest	Amount Simple Interest	Number Years Serial Interest	Amount Serial Interest	Total Simple and Serial Interest	Amount Repaid On Each Dollar Borrowed	Optional Date
Pinedale	37	1910	$ 2,800	....	$ 2,800	1940	6	30	$ 5,040	....	....	$ 5,040	$ 2.80	1925
Rocky Ridge	41	1922	12,000	....	12,000	1952	5	30	18,000	....	....	18,000	2.50	1937
Waverly	49	1920	3,500	....	3,500	1940	6	20	4,200	....	....	4,200	2.20	1930
"	49	1920	4,000	....	4,000	1940	6	20	4,800	....	....	4,800	2.20	1930
"	49	1927	9,000	$ 2,500	6,500	1940	4.5	7	2,048	6	$ 1,327	3,375	1.38	serial
"	49	1928	15,000	....	15,000	1952	4.5	13	8,775	11	4,455	13,230	1.88	serial
Summit	54	1919	9,500	....	9,500	1939	5	20	9,500	....	....	9,500	2.00	1929
Maesner	59	1926	10,000	1,000	9,000	1936	5	....	....	10	2,750	2,750	1.28	serial
La Porte	60	1923	10,000	....	10,000	1943	5.25	20	10,500	....	....	10,500	2.05	1933
"	60	1924	15,000	....	15,000	1944	5	20	15,000	....	....	15,000	2.00	1934
Timnath	62	1918	37,000	3,000	34,000	1938	5.5	20	40,700	....	....	40,700	2.10	1928
"	62	1919	20,000	....	20,000	1939	5.5	20	22,000	....	....	22,000	2.10	1929
"	62	1921	19,500	....	19,500	1941	6	20	23,400	....	....	23,400	2.20	1931
Big Thompson	63	1921	18,500	....	18,500	1951	6	30	33,300	....	....	33,300	2.80	1936–41
All school bonds		1920	$1,210,800	$61,000	$1,149,800	1943	5	23	$1,136,998	....	$258,645	$1,395,643	2.15	1931
County hospital		1924	175,000	....	175,000	1944	4.5	20	157,500	....	....	157,500	1.90	1934
Total county and schools		....	$1,385,800	$61,000	$1,324,800	....	....	....	$1,294,498	....	$258,645	$1,553,143	$2.12	....

Payment of Principal Should Not Be Deferred Too Long.—A period of from 5 to 15 years should not be permitted to elapse between the date of issue of bonds and the date of the first redemption. For example, Wellington, district No. 34, has a bond issue of $61,000 where the period for bond redemption is deferred 16 years before the date of the first redemption begins. Because of the deferred payment of principal, bonds have been issued which are very costly. In 27 out of the 36 district bonds, the interest charges have equaled or exceeded the capital borrowed.

Callable or Redemption Features Should Be Provided.—Provision for callable dates should be provided for in future bond issues. The last column in Table 26 gives the dates when bonds are callable and shows that no provision whatever was made to call bonds in many cases.

Forms of Bonds in General Use.—In considering the issuance of bonds, the two forms in general use are term and serial. Term bonds mature after definite periods and require a sinking fund to be set aside out of taxes or other sources of revenue to meet the principal when due. Serial bonds are retired annually or at other definite periods in regular installments, a fixed portion of the issue being retired each year or at each maturity date. The serial bond is the cheapest and is the most popular for financing schools, highways, etc., and is rapidly replacing sinking fund bonds in county financing. This type is particularly adapted for financing operations which by their very nature involve a depreciation of property. If the retirement of the bonds is faster than the depreciation of the property, then the difference between outstanding bonds in any one year and the value of the property may be termed the margin of safety.

Term or Sinking Fund Bonds.—The principle of the sinking fund is used on most of the county and school bond issues in Larimer County. It is the general opinion, however, that sinking funds are wasteful because they are liable to misappropriation, abuse, market depreciation, or actual loss from poor or declining credit. The successful sinking fund requires considerable financial ability in its management; it is likely to be bad in the case of small school districts and counties where little ability is found among public officials.

Now that investors have come to prefer serial bonds to sinking-fund bonds there is no rational excuse for the latter.

Serial Bonds.—On account of the defects of sinking funds, it is now becoming the custom to employ serial bonds instead. This departure is to be looked upon as a decided improvement

upon the sinking-fund method of retiring obligations. Public obligations, if retired at all, must be retired thru funds accumulated over a period of years out of taxation, since it is impractical to levy taxes sufficient in any one year to cancel large loans. If the bonds are arranged so that a certain percentage of them mature each year, taxes may then be levied sufficient to meet the interest on all obligations remaining outstanding and also to meet maturing issues. This reduces both interest and principal annually and at the maturity of the last bond the entire debt is canceled.

A few serial bonds have been issued by the school districts in Larimer County. These bonds represent advanced methods of financing and more districts should adopt this method of financing bond issues.

The author suggests that serial bonds should be compulsory, and refunding should be prohibited except in the event of extreme emergency.

Registered Warrants.—Warrants are orders on the treasurer issued by the county commissioners or others payable to specified parties or their order. They are of indefinite maturity but normally are paid out of future taxes.

The county's indebtedness in the form of outstanding warrants has increased 483 percent from Dec. 31, 1921, to Dec. 31, 1928. Table 27 shows the outstanding warrants which the county had at the end of each year beginning with 1921. The heavy floating indebtedness indicates that the condition of the county's finances is trending from bad to worse. The county should be able to borrow money at 4 to 5 percent instead of 6 percent if the expense is absolutely necessary. The deficits which have occurred from year to year emphasize the fact that the finances of the county have been poorly managed. These figures reveal one of the sources of waste and loss in the present method of operating the county's finances.

A well-planned and ably directed budget would be of immediate benefit. It prevents waste since it regulates the spending of money for a definite purpose and in accordance with appropriations established by the county commissioners. A county budget system would act as a safety signal for the management of county affairs, since it indicates the variance between its estimates and the actual results obtained from period to period or from month to month. The county finances can be budgeted and to real advantage—the seasons, weather, crops or other conditions notwithstanding.

TABLE 27.—OUTSTANDING WARRANTS IN LARIMER COUNTY, 1921 TO 1928[1]

Date	Total Outstanding Warrants	Distribution of Outstanding Warrants					
		Roads	Ordinary County	Poor	Mothers' Compensation	Blind Benefit	Advertising
Dec. 31—							
1921	$ 72,071.27						
1922	20,587.94						
1923	32,215.27	$ 29,442.32	$ 2,199.90	$ 573.05			
1924	140,349.47	132,686.75	5,546.12	2,091.60	$ 25.00		
1925	175,520.32	146,743.52	16,921.74	5,245.06	5,710.00	$ 900.00	
1926	157,356.72	80,368.97	47,253.79	22,538.96	7,045.00	150.00	
1927	203,528.61	119,174.77	45,124.02	34,049.82	5,030.00	150.00	
1928	348,260.13	261,781.12	50,341.80	31,257.21	1,810.00	1,070.00	$ 2,000.00

[1]Auditor's reports.

Warrant Account for 1928.—For the year 1928, warrants issued against the various funds, warrants paid, and warrants outstanding were as follows:

TABLE 28.—WARRANT ACCOUNT LARIMER COUNTY, 1928[1]

Fund	Warrants Outstanding	Warrants Issued	Warrants Paid	Warrants Outstdg. 12–31–28
Ordinary county	$ 45,124.02	$202,310.44	$197,092.66	$ 50,341.80
Road	119,174.77	407,620.62	265,014.27	261,781.12
Poor	34,049.82	103,239.58	106,032.19	31,257.21
Mothers' compensation	5,030.00	6,340.00	9,560.00	1,810.00
Blind benefit	150.00	5,180.60	4,260.60	1,070.00
Advertising	....	6,260.00	4,260.00	2,000.00
Totals	$203,528.61	$730,951.24	$586,219.72	$348,260.13

The outstanding unpaid warrants were increased $144,731.52 during the year 1928.[2] Interest on registered warrants paid from the liquidation fund amounted to $9,206.23.

Floating Debt.—Floating debt is an indebtedness which calls for payment within a short period of time. It represents the unfunded indebtedness of the county in the form of unpaid warrants as distinguished from bonds or other long-term indebtedness. Debts of this sort should be made to cover anticipated revenues or merely for the purpose of meeting current expenses. Larimer County and many of the school districts have abused this privilege and have floating debts outstanding continuously.

Foating debts are frequently necessary on account of some irregularity in collection of revenues or on account of the fact that expenses often have to be met before revenues are due. Borrowing under these circumstances is unavoidable. The guiding principle which should be followed here is that all current obligations should be canceled at least once a year. This would prevent floating debts from assuming the character of permanency as they have in Larimer County.

County Indebtedness.—At the close of business December 31, 1928, the outstanding bonds and warrants were as follows:

County hospital bonds	$175,000.00
Outstanding warrants (floating debt)	348,260.13
	$523,260.13
Less cash balances in county funds	18,370.00
Net county indebtedness	$504,890.13

[1]Auditor's report, 1928.

[2]The annual audit for 1929 shows that warrant indebtedness was decreased $122,551.59 during the year, $88,944.74 as a result of a 1.60 mill levy for the purpose of paying off outstanding indebtedness and $33,606.85 as a result of savings due to the economy program recently initiated by the board of county commissioners, Feb. 1, 1930.

Wise public financing requires that no loan should be contracted to meet current expenses as has been the case in Larimer County. If expenditures for buildings and improvements come only occasionally, as they do in this county, it is perfectly proper to finance them out of borrowed funds because the benefits accrue to the future as well as to the present. But money to meet purely current expenditures should be provided from current taxes. Even in the case of permanent improvements, if these are distributed so that a normal amount has to be provided annually, they become current expenses and the taxpayers should not be burdened with debts on their account. The pay-as-you-go policy is sound and in such instances cannot be improved upon.

Liability for Creating County Floating Indebtedness

Section 8693 of the Compiled Laws of Colorado state that county expenditures are limited to the annual appropriation. The law reads as follows: "Neither the board of county commissioners, nor any officer of the county shall add to the county expenditures in any one year, anything over and above the amount provided for in the annual appropriation resolution of that year, except as is herein otherwise specially provided. And no expenditure for improvements to be paid for out of any fund of the county shall exceed in any one year the amount provided for such improvements or purpose in the annual appropriation resolution; Provided, however, That nothing herein contained shall prevent the board of county commissioners from ordering any improvement, the necessity of which is caused by any casualty or unforeseen contingency happening after such annual appropriation is made, if there shall be money in the county treasury belonging to the proper fund out of which payment for such improvement can be made."

Section 8694 states that, "No contract shall hereafter be made by the board of county commissioners of any county, and no liability against the county shall be created by any officer of the county, whether the object of the expenditure shall have been ordered by the board of county commissioners or not, unless an appropriation shall have been previously made concerning such expense. And each, and every member of the board of county commissioners, and other officers of the county who shall undertake to create any liability against the county, except such as he is by statute required to do, shall be personally liable, and shall together with the sureties upon his official bond be held for such indebtedness."

Section 8853, however, offers a loophole thru which county commissioners in Colorado are able to escape because present laws are not clear in their meaning. These laws need to be revised so that taxpayers may have some means of protecting themselves against reckless expenditures by county commissioners.

That deficits occur in the county government is not wholly the fault of the county officials. They are in the grip of a system of government which is unworkable under present conditions. The organization and procedure of county government were laid out many years ago and are unsuited for present-day needs.

The county is controlled entirely by state law. There is a great mass of statutes relating to county government scattered thruout the Colorado code. These statutes detail the organization and procedure, at times down to the number and salaries of minor employees. Some are obsolete. Some are conflicting. Many are hindrances to efficient operation.

These facts are not new. They have been repeated many times in recent years. Yet nothing definite is ever done about it. The inertia with which the public nearly everywhere views county government has not yet been broken down. The inertia is in large part due to a lack of information about county government and a failure to realize its importance. Partisan considerations interfere with efforts of public-spirited citizens and officials. All attempts at improvement, whether they are for reorganization of county government, establishment of financial control, installation of mechanical bookkeeping or photostat recording, meet with political opposition or indifference.

Summary

Property owners of Larimer County faced a bonded indebtedness on January 1, 1929, of $4,292,810 in county, school and municipal bonds, or an average of $144 for every man, woman and child in the county.

Taxpayers must repay $2.12 for each dollar borrowed on all bonded indebtedness.

Suggestions are given for reducing interest charges on bonded indebtedness.

The county's floating indebtedness in the form of unpaid warrants has increased 483 percent from 1921 to 1928.

The floating indebtedness amounted to $348,260 on January 1, 1929, an increase of $144,732 during 1928. This floating indebtedness was the largest floating debt of any county in the state in 1928.

The net county indebtedness on January 1, 1929, amounted to $504,890 including both bonds and warrants.

Taxpayers of Larimer County should give credit to the present board of commissioners who have reduced the floating indebtedness $122,552 during 1929.

REORGANIZATION OF COUNTY GOVERNMENT

A study of the county government of Larimer County indicates that the greatest reform is needed in fiscal management.

It is clear that the amount of service that may be rendered by the county is dependent primarily upon the resources of the county and the business methods and practices employed, and the more efficient the business practices, the greater the service that the resources will support. Larimer County possesses large resources but the system of government could be greatly improved. As a consequence the county receives comparatively small returns from the expenditure of public funds because the resources are wasted thru this inefficient system.

Defects in Present Organization

A study of Larimer County government indicates that there are certain defects in organization and management. The defects are similar to those which appear in other counties. The most important defects brought out in this study are:

1. Lack of unified control over entire county business.
2. Lack of centralized purchasing agent to prevent waste and duplication of purchases.
3. Lack of proper inventories, stock records and other methods used to care for and protect the physical property of the county.
4. Lack of proper accounting system safeguarding the revenue.
5. Lack of budget control safeguarding expenditures.
6. Need for better financial control and methods of financing county and school indebtedness.

Moreover, when these defects are removed, the government should improve and present a much higher standard of efficiency, and the service that the people derive from the government should increase.

"The business of providing public services is surely no less important than these other businesses for the security and welfare of the American people, but it differs from them in one significant respect; it is everybody's business, and as such tends easily to become nobody's business.[1] It may fairly be said that

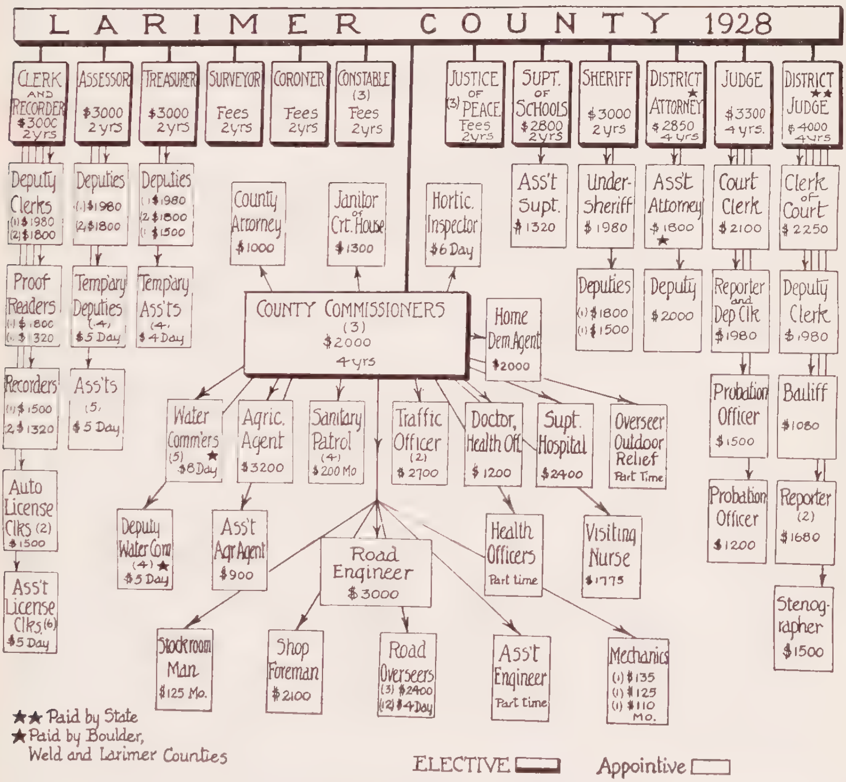
[1]National Industrial Conference Board. Cost of Government in the United States, 1925-26. New York.

the community gives far less thought and energy to regulating and controlling the business of the government than it does to the supervision of other business of far less magnitude. Yet it is the community that pays the government bill, and the responsibility falls upon it to devote at least as much thought to making the business of government efficient, to lowering the cost and improving the quality of the services the taxpayer buys, as has been applied in industry and trade to give the consumer a better product at a lower price."

This section of the bulletin deals primarily with defects in fiscal management and offers suggestions for its improvement.

Unified Control Over County Business Necessary

It seems that the county needs a plan for coordinating all forces and directing them toward the attainment of sound fiscal control. Sound fiscal control demands unified control.



Organization of County Government

Most of the officers of Larimer County are independent of the county commissioners. See Chart 4. Each has been spending county funds on his own initiative, often rendering no statement until the debt is incurred. The superintendent of the county hospital and farm, the sheriff, the various courts, the assessor, the treasurer, and even the janitor for the courthouse buy supplies for their respective offices and submit bills to the county board of commissioners. Even were every officer a wise and honest buyer, a loss would be entailed because of retail buying in small lots.

"Almost everywhere the county is devoid of a definite executive head. No other unit of government, no other corporation, public or private, has attempted to function without leadership. This lack of centralized authority in the county is perhaps more responsible for the deficiencies in county administration than any other single factor. Divided responsibility tempts the weak man to be dishonest; it encourages the plunger to be extravagant; it conceals the mistakes of the stupid; it shifts the blame to the shoulders of the innocent; it nullifies the efforts of the prudent; and it paralyzes the ambition of the genius.

"There has been ample experience to show that the attempt to secure a good chief executive by popular election is a failure. It always gives us a transient amateur who never really learns his job, because he is not allowed to stay on the job long enough. A county is a corporation. No business could avoid bankruptcy if organized as our counties."[1]

In county administration there is an increasing need for men with technical training. The construction of highways, the assessing of property, the administration of the schools, the care of delinquents, the protection of public health, are all matters which should be in the hands of experts. Popular election will not provide trained administrators. The appointment, rather than election, of such officers makes it easier to secure persons who have the proper qualifications. Appointments, however, must be limited to those who are qualified by training and experience.

The county has continued almost unnoticed and unaffected by movements for increased efficiency. In organization it remains basically as it was three-quarters of a century ago, and in administrative methods it follows in large measure the time-worn ruts of past decades.

The truth is that the county violates every principle of business and of governmental organization which experience has evolved. It is indeed the product of centuries of slow but largely

[1]Paul W. Wager. County Government and Administration in North Carolina. p. 396, 402. 1928.

hit-or-miss development. In some of its features it dates with comparatively little change from medieval England. The coroner's office, which has been the butt of jokes for a generation, has its origin in the thirteenth century, and has remained more because of inertia than because of any real necessity. The sheriff's office is likewise an inheritance.

No other branch of government is so decentralized in administrative authority as the county. See Chart 4. As a business organization it lacks a responsible head, having no official corresponding to president, governor or mayor in national, state and municipal government. Executive responsibility is scattered, some devolving upon the county board of commissioners, and the remainder resting with various independent officers who are selected with little apparent logic by the electorate, the board, the court and various officers. Moreover, most terms of office are very short, encouraging frequent changes in posts such as treasurer, assessor, clerk and recorder, and the like, where experience and even permanence are valuable.

Chart 4 shows that there are 13 elective offices and a host of appointive positions. Each elective office is practically independent of all the others. This division of authority is found in essentially the same form in all Colorado counties except Denver County. It breeds wasted effort and lack of coordination. It also obscures responsibility. Such a system embodies all the ingredients that normally lead to wasteful methods and therefore to unduly high taxes.

In order to accomplish needed changes in organization, the whole structure of county government in Colorado needs to be reorganized. Certain sections of the state constitution should be amended to permit the modernization of an obsolete system.

County officials are powerless to make many needed changes because we are using the system of a half century ago with little or no modification.

County Manager Form of Government Suggested

Rapid progress toward a highly efficient and economically administered county government could be made by the appointment of a county manager.

If the constitution of Colorado were amended and modernized the county commissioners could appoint a county manager who would be the administrative head of the county government and who would be responsible for the administration of all departments of the county government except those of a judicial

character and those pertaining to elections. He should be appointed with regard to merit only, and he need not be a resident of the county at the time of his appointment.

The results obtained under the manager form of government have been extremely satisfactory where it has been tried out. These managers have lifted much of the responsibility of the detail of county affairs from their respective boards and have safeguarded the interests of the counties which would otherwise have gone neglected. They have been able to furnish invaluable information and render intelligent advice to their boards in carrying on the business of the counties more wisely and economically.

The main obstacles which prevent the accomplishment of desirable reforms, such as consolidating offices,[1] combining like or similar functions of local government, reorganizing county government into one unit where possible, are the reluctance of the people to change their form of government and the failure of the political leaders to support such proposals. They use the railroad, the motor vehicle, the airplane, the telephone, the radio and all other modern inventions, but when it is a matter of government, they believe that the form employed in the ox-cart days is equally suitable today.

That politicians do not favor any governmental reorganization or consolidation which will reduce the number of officers and employees is not surprising. Political organizations live and exist on political patronage. The perplexities and troubles of the political leaders will, of course, increase if they have fewer jobs to pass among the faithful. Notwithstanding this, if we are to have economy and efficiency in government, and thereby the lowest taxes consistent with good government, it is imperative that we recognize the need for modernizing our governmental organizations.

Need for Central Purchasing Department

There is need for a centralized purchasing department in the county. At present, supplies of the same sort are purchased from a variety of sources. A very considerable and substantial saving could be made each year by a thoroly trained and competent county purchasing agent. The prices paid are directly reflected in the high operating costs, while the prices paid for equipment[2] and other outlays are directly reflected in the capital outlay expenditures of each department and the county as a whole.

[1]This would require a constitutional amendment in Colorado.

[2]See appendix for prices of equipment purchased.

Costs may be kept down by quantity purchases under a competent purchasing agent who is qualified to secure and judge prices, bids and materials. Recently a Weld County official mentioned that his office could make a considerable saving if Larimer and Boulder counties would standardize certain legal forms and make cooperative purchases with him. Another example is in the purchase of groceries, coal, etc., from the poor fund. In this case supplies are purchased from almost as many sources as there are dealers and grocery stores.

One of the most amusing illustrations of careless purchasing is that of Larimer County permitting the janitor to purchase supplies for the court house. According to the commissioners, the janitor purchased $1,614 worth of soaps and disinfectants for use in the court house in 1925, $1,093 in 1926, $1,286 in 1927, and in 1928, bills for $5,254 were presented for payment. Quoting from the local paper, "Has there been an attempt to 'soft soap' the county?" Centralized purchasing would prevent such waste and losses.

There are 138 school directors in Larimer County which means 138 purchasing agents, many of whom are competent and qualified to purchase supplies. However, many school directors are not fitted for this particular job and as a consequence costs are high or the kind and quality of supplies are unsatisfactory.

It is recommended that a careful study be made of the needs of the county school department; that a special survey be made of this particular problem with the view of ascertaining the advisability of having a purchasing agent handle all the purchasing requirements of the various school districts.[1] Other states find it practicable and recently the state of California passed a law placing the buying of all supplies in the hands of the superintendent of schools, at his or her option. North Carolina passed an act making it the duty of the county commissioners to provide for centralized purchasing in order to prevent waste and duplication in purchasing.

The central purchasing department of the county upon which requisitions could be made by the local school districts or county departments, is able to use greater discrimination in selecting machinery, equipment and supplies, than the members of various departments when acting alone. In the matter of intelligence, the single purchasing department can devote considerable time to a study of the relative costs of different materials and supplies, paper, ink, office equipment, electric lamps, lumber, road graders, etc., as the case may be, and purchase standardized

[1]Mr. N. Woodard, a graduate student in the Department of Economics is now making a study of central purchasing of school supplies.

equipment for all divisions. Economies, too, are often possible in the purchase of standard equipment, even where no discriminating judgment is required.

If the county does this work intelligently and does its buying wisely, it not only gets what it bargains for, and saves money, but it raises the standards of business, and benefits the general public. On the contrary, if it buys with inadequate specifications, and accepts goods without tests, it lays its representatives open to charges of favoritism, encourages misrepresentation, and defrauds the taxpayer who ultimately pays the bill.

Care and Protection of County Property Essential

Larimer County has failed to take proper care of its physical property, and should delegate this responsibility to a county manager or some other officer. The lack of any regular and systematic inventory or property record has made it impossible for the county commissioners to know at what rate machinery and other property depreciates. The county should keep a property record which will show all purchases of new equipment and charges to the proper department or individual. Proper acccounting for capital outlay and depreciation should be provided. This is particularly desirable for machinery and equipment such as trucks, tractors and road machinery. At the present time the annual costs for the use of machinery and other equipment cannot be determined. This simple improvement in county administration need cost very little, but the potential savings are tremendous.

Larimer County Needs a Modern Accounting System

There should be a county auditor to preserve and maintain a proper coordination of all accounting activities. At present there is no method for coordinating accounts in the commissioners', county clerk's, treasurer's and other offices. My suggestion would be to create a department for complete control over all accounts and finances. This department should have control over all accounts, statistics, budget and centralized purchasing operations. Large savings could also be made if the assessor's and treasurer's offices were combined. The accounting department should be under the direct supervision of the county manager or county commissioners.

As pen-and-ink and slow, inefficient mechanical methods are passing out of existence in business administration, so are they passing in county administration. There may be no urge to save money on salaries and wages, but still there is that instinctive

desire to do the job better, more timely, more accurately, and to derive more information therefrom. This can be accomplished by the installation of labor-saving devices.

Accounting machines are now being used by hundreds of state, county and city offices thruout the country. These systems of accounts are so comprehensive and complete as to provide instantly all of the information which could be reasonably asked, and so flexible as to meet the demands of the most swiftly growing county.

The average county official is quite unconscious of his limitations as an accountant. He sees no need for anything more than a cashbook record of receipts and disbursements. Balance sheets, control accounts, cost-accounting, are terms which mean nothing to him. The customary method seems to him quite adequate, and he attempts to follow in the footsteps of his predecessor. Financial records are scattered, and most of them incomplete and in a state of disorder. These conditions are often the result of incompetence and the system of keeping accounts. Relief for the taxpayer from this system is imperative.

A Budgetary System of Accounting Is Needed for Larimer County

The accounting problems of Larimer County are many and varied. Mechanical equipment is now available to handle this important and varied type of accounting. The machines give all the results necessary to control the budget and appropriations, revenue and expenses, and disbursements and available cash. They give this information accurately and complete each day, with the highly important balances in each account to control the appropriations and expenditures, enabling the instantaneous compilation of daily, monthly and annual reports.

With the present system one is unable to obtain even an annual report on some phases of county expenditures several months after the books are supposed to be closed.

Need to Provide for County Fiscal Control Thru a Budget

A complete budget system should be installed in Larimer County without delay.[1] This county needs a budget at this time in order to place it in a sound financial condition. Its purpose is to place a competent accountant in charge to guarantee a bal-

[1]About Nov. 1, 1929 the Larimer County commissioners asked various departments of the county to submit estimates of expenditures for 1930 in order that the county might be placed on a budget plan.

anced budget and incidentally discourage wastefulness and fraud and render to the taxpayers an accounting which they can understand.

A budget is the mapped plan for the future progress of a county business. It is as necessary to the county as the navigator's chart is to the mariner. It deserves and should have the careful consideration of every county which desires a better control over the future of the county business.

By no other means may the county so quickly come to a realization that there are deficiencies in its form of organization or personnel than thru an earnest attempt to establish and operate a budget, because successful budgeting depends so much upon good organization.

Tax Office Efficiency

Every one who is familiar with the tax office is aware of the cumbersome procedure and the vast amount of duplication of work and of the seemingly unnecessary amount of work required to bring to completion the annual job of compiling tax rolls. In Larimer County this is all done by long-hand methods. The assessor is familiar with the difficulty in securing efficient extra help to complete the rolls within the allotted time.

If, for example, the tax assessment notice or tax bill and tax roll can be written in one operation, with absolute proof of accuracy, there is no reason why the assessor should continue to do the work under the old, inaccurate, time-consuming method.

Each year the complete list of 12,000 schedules and a much larger number of pieces of property has to be individually written three times on the assessor's bill, the tax roll and the tax bill. Many of these schedules have from 20 to 25 pieces of property, each of which has to be described. Then, the next year it has to be written three times more, and about 90 percent of the descriptions remain the same each year.

Each time the complete list is transcribed it has to be checked for accuracy. In other words, approximately 50,000 names, addresses and descriptions have to be checked and proved correct each year. This requires a large number of clerks for a considerable period.

By means of electrical automatic machinery it is possible for one clerk to compile the tax rolls and tax bills, where it would require a number of clerks to do this same work by long-hand. To run off the descriptions and addresses on the machine is but a matter of a few moments. No checking whatever is necessary, as the plate once made correct will transcribe an exact description.

Indebtedness Should Be Reduced and Borrowing Policies Changed

Indebtedness of Larimer County has been built up without a definite financial program until it represents a total of $504,890.13 on December 31, 1928. This rapid increase in indebtedness is explained largely by the widespread demand for improved roads and other services.

The idea of building good roads is highly commendable if the work is well done and if the improvements are financed in the best way. It is questionable whether the creation of a large floating indebtedness is the best way in which to accomplish the work. If the $350,000 floating indebtedness is funded it will cost the taxpayers about $750,000 to liquidate this debt with absolutely nothing to show for their sacrifice.

Taxpayers should examine the annual indebtedness incurred by the county commissioners and bring pressure on them to reduce and control it. In fact, it looks like the time has arrived when the county should consider seriously a pay-as-you-go policy and begin to reduce the heavy interest charges and indebtedness.[1]

APPENDIX—TABLE A

Portion of the Road Equipment Purchased, Larimer County, 1926 to 1928[2]

Jan. 1, 1926 to Dec. 31, 1926

1	Russell road finisher	$ 710.00
24	No. 2 Zenith shovels	43.70
3	Gas pumps	91.43
1	Gas pump	30.25
1	Dodge car	1,010.00
1	No. 920 Cedar Rapids rock crusher with bin	5,161.36
1	Adams wheel grader and extra blades	429.50
1	Drive belt	230 30
12	No. 2 Drag scrapers	175.26
4	No. 2½ Western wheelers	408.24
1	Adams wheel grader and road plow	466.12
1	No. 6 Western plow	43.11
24	No. 2 Long handle shovels	43.20
1	45 3-8 x 96 vertical type boiler	824.70
1	Adams road patrol	158.45
1	No. 5 Western railroad plow	47.27
12	No. 2 Western double bottom slips	168.84
2	Rawls highway mowers	737.41
1	Alemite compressor	75.00
1	Adams leaning wheel grader	416.60
3	Model 10 B snow plows	1,100.00
		$12,370.74

[1]County commissioners on January 28, 1930, stated that they planned to reduce the indebtedness without resorting to funding operations, reducing the indebtedness thru the increased mill levy and thru a program of economy.

[2]Auditor's report.

Jan. 1, 1927 to Dec. 31, 1927

1	Anthony gear controlled dump body	$ 162.00
2508	ft. all metal snow fence	1,906.08
1	Adams leaning wheel grader	1,817.55
2	No. 2 Western sheeled scrapers	180.22
1	F 2 Hoist complete	377.29
1	Ford ton truck	848.55
1	Standard highway maintainer	385.00
1	Air compressor	373.55
1	Fleming H. D. regrooving machine	105.50
1	No. 21 Western groundhog plow	89.15
1	Little western road grader	225.00
36	No. 2 Long handle dirt shovels	69.11
4	No. 5 Western railroad plows	186.10
1	No. 3 Western fresno	32.00
1	No. 1 Western fresno	36.00
1	No. 21 Western groundhog plow	97.28
1	Russel road finisher	710.00
1	Servis road shaper	385.00
1	Elevating grader	300.00
	Log chains	95.55
1	Russel road finisher	655.00
1	No. 5 Western road plow	47.25
6	No. 3 Dirt shovels	12.90
1	Double drum Fordson hoist	500.00
1	Fordson power scraper	380.00
1	No. 2 Aeroil torch and tank, etc	85.45
1	B. G. U. conveyor	150.00
1	Single burner tar kettle heater	82.50
1	Wagon tank	50.00
1	Buda 40 H. P. engine	358.00
2	Air hammers	195.00
1	Adams leaning wheel grader	424.00
2	Adams road patrols	315.00
48	No. 2 Round point dirt shovels	92.16
1	50-ft. 2-ton electric crane and steel structure	2,950.00
1	Ford roadster	150.00
2	No. 5 Western road plows	94.60
36	No. 2 Long handle dirt shovels	68.44
24	No. 2 Western double bottom slips	322.08
1	Western midget grader	175.00
1	Small range	10.00
1	No. 3 Blasting machine	30.30
1	Ford roadster	125.00
1	Paint spray gun	44.40
	Payment on caterpillar No. 60	2,642.50
1	Mower	40.00
1	Steel crusher, conveyor belt and steel bin	6,500.00
3	Fresno scrapers	35.00
1	Engineer's transit, case and tripod	125.00
1	Compressed air power reamer	163.23
1	Servis road fixer	385.00
1	Tractor engine, hoist, etc	1,615.15
	Payment on Liberty truck	2,000.00
1	Adams leaning wheel grader	410.00
36	R. P. dirt shovels	69.07
2	Ford trucks	1,726.60
1	Ford truck	250.00
3	Ford trucks	2,589.90
1	Ford truck	933.50
1	Klauer service scarifier	1,904.00
		$37,086.96

Jan. 1, 1928 to Dec. 31, 1928

1	Capitol Chevrolet coupe	$ 801.00
	Balance due on Liberty truck	4,000.00
1	Adams leaning wheel grader	1,918.00
1	Sauerman Fordson Crescent outfit complete	414.50
1	Revolving screen and elevator	1,022.50
2	No. 4 Champion crushers and elevators	5,350.00
2	No. 1 Atlas portable conveyors, etc.	1,077.30
1	No. 2 Servis road shaper	702.00
24	No. 2 Western double bottom slips	343.95
1	Adams road patrol	165.50
1	Adams leaning wheel grader	441.96
1	Hanson 3-8 yard full revolving excavator	5,750.00
1	Ford truck	310.00
1	Caterpillar 60 tractor No. 2266 P. A.	5,417.00
	Balance due on caterpillar 60 No. 1658 P. A.	2,734.98
1	Western No. 3 road plow	74.22
84	No. 2 Zenith long handle dirt shovels	161.21
1	Bed monarch standard pattern lathe, etc.	2,360.10
1	Model S. B.-44 International H. Co. truck	2,000.00
1	Wall tent	69.00
12	Western double bottom slips	174.09
3	Road drags	675.00
1	Little western road grader	287.31
	Part payment Buick truck	900.00
1	I. H. Co. motor truck	1,869.00
1	Western No. 6 road plow	43.76
1	No. 3 Adams road patrol	165.50
1	Gasoline tank	60.00
6	Road rakes	12.90
48	No. 2 Zenith long handle dirt shovels	92.13
1	Bass adjustable road drag	203.68
	Balance due on snow plow	1,493.50
	Balance due on caterpillar 60 } Balance due on caterpillar 30 }	7,598.80
1	Wall tent	30.00
1	Adams leaning wheel grader	1,630.00
1	Monarch model No. 50 tractor	3,805.00
48	No. 2 Zenith long handle dirt shovels	80.05
4	Western slips	56.80
1	Western No. 20 rooter plow	63.88
	Balance due on Buick	900.00
1	Adams road patrol	170.50
1	3-8 yard bucket	429.12
1	Adams road patrol No. 3	165.50
1	Fairbanks Morse centrifugal pump	77.40
1	No. 5 Western road plow	53.75
2	No. 3 Western fresnos	72.00
1	McCormick Deering industrial tractor	1,625.00
1	Baker maintainer	872.00
1	No. 5 Western road plow	55.60
12	Sidney great western slip scrapers	194.72
		$58,970.21

Summary

There are certain defects in the organization and management of the county government, the most important of which are as follows:

Lack of unified control over different departments.

Lack of proper accounting.

Lack of a central purchasing department.

Lack of an effective budget system which will control governmental extravagance.

Need for better methods of handling indebtedness.

The county-manager form of government is suggested as a remedy for the lack of unified control, but this will require a revision of the state constitution. The whole system of county government needs to be reorganized and simplified. Simplification of the county government will permit the voters to bring steady and persistent pressure upon the executives in control.

At present the county commissioners are powerless to inaugurate many of the reforms which are greatly needed because they lack the power to appoint and remove all executive officials.

Bulletin 362 January, 1930

EFFECTS OF CLOVER AND ALFALFA IN ROTATION

PART II

BY WM. P. HEADDEN

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EFFECTS OF CLOVER AND ALFALFA IN ROTATION

PART II

By Wm. P. Headden

There is seldom so close a correlation between the chemical analysis of a soil and its productivity that inferences can safely be drawn from the analytical results alone. So far as analytical results are concerned very productive land may differ so little from unproductive that no distinction can be made. The difference between the two soils depends upon something besides the small and possibly uncertain differences shown by the analyses. Factors not in any way indicated by the analyses may be the determining ones. The mineralogical features of soils may have a general resemblance or they may differ greatly and yet both the soils be productive.

Our loams and adobe soils are very different, with some features in common and both may be good productive soils. The loams contain practically four constituent minerals—quartz, felspar, calcic carbonate and clay. The adobes are finer in texture, more clayey, often rich in calcic carbonate and are often rather intractable. The origin of the two may be quite different, yet the adobe, a less desirable soil, may be very productive.

This statement contemplates them in their natural condition, i. e., without the aid of fertilizers or amendments. The yield of wheat is possibly the most universally applicable measure that can be adopted. The soil treated of in this bulletin and in Bulletin 319, yields, in average years, from 35 to 65 bushels per acre. The largest crop that I have harvested was 66 bushels per acre, but a yield as high as 80 bushels has been recorded for similar land. Our land did not make favorable response to chemical manures and to the application of nitrate the response was in some cases very adverse.

Response of Our Land to Fertilizers

It may be a question whether these conditions are favorable ones under which to study factors that may affect the productiveness of the soil. In this case the conditions relative to the

On former occasions I have felt that the faithful and interested aid of my assistants called for special mention in token of my appreciation. In this work the labor has been divided. Earl Douglass has followed the carbon dioxid and the cultural treatment of the plots; C. E. Vail has done most of the nitrogen and potash work; and J. W. Tobiska has done practically all of the soil analyses. This division has not been so strictly adhered to that cordial cooperation has in any degree been interfered with.

amounts of plant foods present were so nearly optimum that the addition of phosphorus or potassium produced no effect upon the growth, period of ripening, or yield. The potassium did affect the quality of the grain produced. On the other hand, the addition of Chile saltpetre at the rate of 250 pounds per acre was sufficient to make so marked a difference in the plants as to be a matter of comment by the casual observer. It caused hard, shrunken berries and materially reduced the yield of one variety and did not materially increase any yield. The amount of nitrate added may seem large to some, being equal to 10 parts of nitric nitrogen per million parts of soil, but we thought we were adding very moderate quantities as we knew that soil from this field actually developed as much as 325 p. p. m. under fallow cultivation.

THE LIMITS OF ANALYTICAL ACCURACY

It suggests itself very often that our analytical results are wholly inadequate to give any trustworthy information in respect to these questions. The amount of nitric nitrogen added, 10 p. p. m. of the soil, is only 0.001 percent, but this was far beyond the advisable amount to add. In the case of nitrogen our methods are very exact, but it is evident that even in this case they are taxed to give results that are significant and this is true (to a greater extent) even in regard to the phosphoric acid and potash. These factors cannot be omitted, but the productiveness of any soil is very dependent upon its physical properties and the weather. The skillful farmer who is thoroughly acquainted with his soil may do much in maintaining a good physical condition, but even in this he may be defeated by the weather.

Ordinarily we think of the plants as obtaining the mineral elements necessary to their development from the solutions of those that occur in the soil; in other words, the water in a soil in which, for instance, it may constitute 15 to 17 percent of its weight, is a dilute solution of these mineral elements. How this solution has been effected is not clear. The water that falls as rain or is added as irrigating water may be the solvent, in which case we should have an aqueous solution, but this can scarcely ever be the case, for, as soon as it dissolves salts of any kind, the reaction becomes complex and the equilibrium of the solution is probably constantly being disturbed. This solution is similar to a nutrient solution which is constantly being renewed. Whether it is formed rapidly enough to supply the plants continuously with enough foods to meet their needs de-

pends partly upon the rate of solution and its movements in the soil and partly upon the extent of the root system.

There are changes taking place in the soil that promote the solvent action of water. The changes which organic matter undergoes, whether added as manure, or as simple remnants of the vegetation produced on the soil, are constantly furnishing carbonic and other acids that may play a part in determining the character of the solution, more particularly its concentration.

Much has also been said about plants excreting through their roots acids other than carbonic acid, which have been supposed to act upon the soil particles as solvents. Hence we have the conventional 1 percent citric acid as a solvent in imitation of this. This, being an organic acid and in a weak solution, is thought to give us results that correlate with the productive capacity of the soil. The root hairs of the plants are pictured as attaching themselves to the soil particles and described as acting upon them by acid excretions.

There is no question about the activity of the root hairs, but whether this is the manner in which they act may be a question and I do not know what proofs support these claims, nor how satisfying they may be.

SALTS ABUNDANT IN OUR SOILS

In our soils the water-soluble portion is much greater than usual, owing to the lack of leaching in the past with the consequent accumulation of the decomposition products of the constituent minerals. These often form strong efflorescences completely covering the soil with a white coating which is collectively designated white alkali. It is sometimes desirable to wash these soils to obtain these soluble salts for analytical studies, but the results are always involved in some doubt, especially if one attempts to apply them to questions of productiveness. We have done much work of this sort, but the question had in view was always what bad effects they may produce. There are so many instances of excellent crop results in the presence of large quantities of these soluble salts that we have come to believe that in themselves they are usually not in the least harmful in our case.

The preparation of these water-soluble salts presents some difficulties aside from the mechanical ones. There is no criterion by which one can with certainty judge when the sample has been washed sufficiently. We have tried various procedures, none of which is wholly satisfactory. In some cases I have taken the disappearance of the chlorin from the filtrate,

in others that of the sulfuric acid, as indicating a sufficient degree of exhaustion. Either point is often difficult to attain. It is to be borne in mind that we are not in these cases concerned with a few hundredths of 1 percent, but with quantities up to 12 or more percent of the sample. It has not been uncommon for us to use 20 or 25, sometimes 40 liters of water, and to continue the extraction for 10 or more days. This is a laborious business and one is far from satisfied with the results; they represent too much. Any soil treated with 25 liters of water in successive portions of, say, 2 liters each will give up such amounts of salts as to render the results unreliable if we attempt to apply them as a basis of judgment in regard to the productive capacity of the soil.

A different view may be taken of the case, i. e., in very many instances in which such amounts of soluble salts are found in the soil they are associated with more water than may be desirable, and this is a continuing condition in the presence of abundant soluble salts, which can easily be demonstrated to react strongly with the soil particles.

Sodic chlorid, for instance, is so good as always present in these so-called alkalis and a solution of this salt acts strongly on finely divided felspar, eliminating potash principally, but also other salts. It is quite certain that a similar reaction takes place when we treat a soil sample in the vigorous fashion that has been described, but the extent to which this takes place would be difficult to ascertain and probably varies with each individual case.

In cases where there is no excess of water these salts are not absent, but simply less abundant or perhaps only less apparent. The solution in the soil may be as concentrated as in other cases, but probably not, as the accumulation of water is generally accompanied by translocation of salts from other lands.

This fact leaves us in doubt as to how we are to consider the potash, for instance, that we may find in the extracts of alkaline soils, i. e., whether it belongs to the solution proper or has been taken from the soil proper in the individual case. We find potash so generally present in our ground waters that it would be misleading to make exceptions. In 108 ground waters that I have looked over there is not an analysis in which potash does not appear, and it fails to appear in only 5 analyses out of 116 soil extracts. The amounts that appear are often 3 or more percent of the extract or, in case of waters, of the dried residue. The significance of these percentages depends, of course, upon the percentage of the extract or amount of resi-

due. In the analyses referred to, the water-soluble portion ranged from 1 to 12 or more percent and the potash in the analyses when computed on the soils is certainly worthy of consideration in every problem concerning crop production.

The occurrence of potash is in strong contrast with that of phosphoric acid, which occurs only seldom and then in small quantities. Here again the ground and drain waters may show its presence, but it is usually absent, at least not reported.

POTASH IMPORTANT IN CROP PRODUCTION

The part played by potash in the production of crops is apparently of great importance and the volume of the crop agrees more closely with the supply of potash than with that of phosphoric acid or of nitrates. While these three are indispensable, the volume of the crop correlates more closely with the potash available than with the other two. In the case of wheat the grain will tend to mealiness when a relatively excessive amount of potash is present, but to a flinty condition with an excessive supply of nitrogen. In the latter case the volume of the crop is likely to be depressed.

These statements concerning the prevalent occurrence of potash in our soil solutions have not been made with any reference to the allegation that seed of hard wheat varieties imported into Colorado produces soft wheat. They have in this connection, however, some interest as we find that the mealiness or softness of wheat is greatly affected by an abundant supply of potash, and these facts go a great way toward furnishing a satisfactory explanation of this very generally observed fact.

ACID EXTRACTION OF SOILS

The question of how to ascertain the amount and relative quantities of plant foods in a soil available at any given time has given investigators a good deal of concern. I think that nearly all of them agree that acid extraction is not a very good method, for even a weak acid, fifth-normal nitric acid for instance, is not a very good imitation of the processes that are going on in the soil. Even water, used as has been described in the extraction of the total solids soluble in this menstruum, fails to give a faithful representation of conditions as met with by plant roots in that soil. In such extractions we frequently have used from 40 to 80 times the weight of soil extracted and continued the operation for 10 to 14 days. It required this excessive treatment to reduce the chlorids or sulfates, as the case may have been, to negligible quantities in the solution and

sometimes to bring about deflocculation of the clay—a condition that should usually be attained in washing an alkali soil. Such a procedure has but little or no object in the examination of an ordinary soil in regard to its supply of soluble mineral constituents. The soil particles are themselves attacked and the soluble salts extensively changed in quantity and possibly in quality also.

It is a question whether the available mineral constituents of a soil actually exist in dilute solution in the soil, but we suppose they do and may be caused to diffuse into the solution if this be greatly increased for a brief period and then removed. This may be our most advisable procedure, our nearest approach to the actual conditions existing in a freshly taken sample; but it leaves a great deal to be desired. Even in this way we probably alter the ratios and obtain too much in solution. Still we have used this method on our samples without drying them, making a moisture determination to enable us to bring our results to a dry basis. The methods used are those adopted by the Bureau of Soils, U. S. D. A., some years ago.

OUR PROBLEM

Our problem, to determine to what the benefits of a rotation of alfalfa or clover are due, is in its gross features, not so very complex. Perhaps the most evasive question would be, what are the mechanical effects. A good stand of alfalfa may be taken as 250,000 plants per acre. A "good stand," according to actual counts, varies from 125,000 to 525,000. The roots of alfalfa are seldom less than 6 feet long and often 10 or more feet, and vary in size from 1/4 to 2 1/2 inches in diameter. I think that we may assume 1/2 inch diameter and 7 1/2 feet long as a fair, average, alfalfa root in our soils. Clover roots are comparatively small and much shorter than the alfalfa.

It is evident that it would be somewhat presumptuous to attempt to give any estimate of the mechanical effects of a crop of alfalfa on any ordinary soil. We have not only the penetration of the soil by the roots, but the additional fact that each hole thus made is filled with organic matter, very active while living and well distributed when dead and decaying. While we do not know all of the effects produced, we are satisfied that they are considerable and beneficial and in no case to be left out of the reckoning. The fact is we take these for granted even if we cannot give any numerical measure for them.

ALFALFA AND MICRO-ORGANISMS

What the effect upon the microbiological factors of the soil may be can be approached only indirectly in our work and

our inferences are not in harmony with what I infer to be the generally prevailing views in regard to this relation. As we have chosen the carbon dioxid in the soil atmosphere as our rough measure of this relation, we may be allowed to specify what we understand this factor is considered to be, i. e., that it is due largely to the micro-organisms, much more so than to the plants. The neighborhood of the plant roots is considered an area of very active microbiotic activity, much greater than would be the case if the plant were not present. If the plant or any part of it dies it falls a prey to putrefactive changes and this process may be going on simultaneously with the growing of the crop.

In these ways the organisms are believed to be more active producers of carbon dioxid than the plants, even though some organisms can use the carbon dioxid as a source of energy, diminishing the apparent production. These questions do not fall in our province, but we have followed the variations of the carbon dioxid in soil, both fallow and planted to alfalfa, clover, wheat, mixed grasses and corn (maize). These relations are subsequently given in detail. Carbon dioxid is not considered among the plant foods in the soil because it occurs in the air and is mainly, if not wholly, taken up and elaborated into new compounds in the leaves. This is not the case with the nitrogen, potash, or phosphoric acid used by such plants as alfalfa and wheat. These are the usual substances added to a poor soil to make it more productive. We are not concerned with any theory of fertilization, only with the big facts generally accepted and abundantly proved that the addition of these substances to soils of low productive capacity increases the production and this is the object of a rotation of crops. This may be effected by improving the sanitary conditions of the soil, by the possible addition of nitrogenous organic material, and by increasing the amount of soluble potash and phosphoric acid.

THE EFFECTS OF GROWING CROPS—CLOVER AND ALFALFA

The growing of a crop, especially one that is removed from the land, cannot add to the total amount of potash or of phosphoric acid in the soil. It might change the availability of these in the soil, i. e., change the form in which they are present, but so far as the quantity is concerned, every crop removed from the land diminishes the amounts of these two elements that may be present. If the rotation benefits the soil by producing a contrary effect, it must be in some other way than by a direct addition of them. This matter stands differently with the nitrogen.

The wheat and other grasses, however, depend upon the nitrogen in the soil for their supply of this element, as well as for the other needed elements, and consequently tend to reduce the amounts present.

The legumes, i. e., the clover and alfalfa in this case, are different in that they serve as hosts for certain organisms, by virtue of whose presence they are enabled to draw upon the atmospheric nitrogen for a portion of their supply. In the absence of these organisms these plants, like other green plants, use the soil nitrogen for their growth and their requirements are very big. They are heavy-feeding plants; dry alfalfa hay carries about 9 percent of ash, and a little more than 2 percent of nitrogen. For every 4½ tons of hay, 213 pounds of potash and 40 pounds of phosphoric acid (P_2O_5) are removed from the soil. This amount of hay contains in round numbers, 200 pounds of nitrogen. The average crop of alfalfa in former years was actually 4½ tons, but has fallen to about 3½, according to my best information.

As we have these three food elements almost exclusively in view we will consider only these. It is evident that we are taxing ordinarily good soils heavily when we withdraw with every 4½ tons of hay removed the above amounts of plant foods. This nitrogen, however, comes partly from the air and partly from the soil. I have never met with any apparently well-based estimate of how much is obtained from the respective sources and it does not matter to us, for our question is in regard to the amount of nitrogen in the soil after the crop has occupied it for 2 or more years. The general view is that the soil is actually richer in nitrogen after than before the crops were grown. This is a very natural inference from the facts that the leaves are constantly falling off and collect on the surface of the ground and also that in making hay there is a big loss, seldom less and often very much more, than 20 percent of the total green crop. The leaves carry, as a rule, rather more than 3 percent of nitrogen and are very rich in ash—12 to 15 percent. It seems self evident that in this way a good deal of nitrogenous organic matter is actually added to the soil. The surface soil, scraped up with the remnants of these leaves and stems in it, is found to be actually a little richer in nitrogen than surface soil without this debris, so this inference is not unreasonable even though its application in the explanation of the benefits accruing to the soil due to the rotation is not justified by its quantity. This subject will be treated in detail in another section. The present object is to point out definitely the objects of this study, for I have stated that in their big

features they are not very complex and this makes it evident that no attempt is to be made at exhaustiveness or detail.

The question of potash used has somewhat the same complexion as that of nitrogen in that it is freely appropriated.

Clover is not extensively grown in Colorado, though it does well in most sections. The composition and ash content is nearly like alfalfa. Water-free clover hay, Colorado grown, carries ash, 10.63 percent; alfalfa, 9 to 10 percent; crude protein, 14.18 percent; alfalfa, 14 to 15 percent. The ash of clover hay carries potash (K_2O), 26.80 percent; alfalfa hay, 28.0 percent. The alfalfa ton for ton, carries rather more of both nitrogen and potash than the clover and will produce more tons of hay. They are both heavy feeders and excellent members of a rotation.

The potash in the soil presents different questions from those presented by nitrogen. In every soil there is a definite amount present which is seldom or ever increased by natural causes, whereas the nitrogen is not a fixed quantity, but one that varies continuously in quantity present and in its form. All plants require that this nitrogen be prepared for them. Most plants require that it be presented to them in the form of nitrates, which is effected by the soil organisms. Some of these organisms gather the atmospheric nitrogen and through their agencies it becomes available for plant growth. No such thing as this can happen in the case of the potash. The sum total is there to begin with and debarring its removal in the form of crops, it practically all remains there. A little may be removed by drainage, but this amount is small.

MINERAL CONSTITUENTS MUST BE SOLUBLE

Plants obtain the whole of their mineral constituents from solutions and if the whole of the potash in the soil were insoluble, plants would not grow in it. How much potash must be brought and held in solution at any one time in order for alfalfa or potatoes, for instance, to make a maximum growth, I do not know. Nor have I any notion of what percentage of the soluble potash present is actually appropriated by either of these crops. I cannot believe that a maximum crop can be grown with an amount of soluble potash present which is barely sufficient to furnish the amount required by the crop. I have seen the statement that very dilute solutions will suffice so long as the total requirement is met. Our problem does not require any consideration of this question.

The potential supply of potash in our soils is abundant. Our average lies between 2.25 and 2.50 percent of the air-dried soil. Air-dried may be taken as meaning about 3 percent of moisture. The percentages given indicate that an acre-foot of our soil contains from 45 to 50 tons of potash (K_2O). Of course, this is not soluble in water, at least not quickly. In ordinary language this is insoluble and must be brought into solution by some means before plants can use it. Weathering, a name used to designate a series of changes or decompositions brought about by climatic condition, cultivation, manuring, even with potash-free manures, prepares this potash for the use of plants.

I have said that only small amounts of potash are lost by drainage, even though the potash to be available to the plants must be soluble in water. Any loss of this sort is prevented by the properties of the decomposition products of the soil themselves, which hold a good deal of this substance loosely, not so firmly that it cannot be obtained by the plant, but firmly enough to prevent its being carried away by the ordinary water supply. This function is exercised by the compound particles built up in the soil, often called aggregates. In most of our soils these aggregates are not very firm and excessive water breaks them up and our soil puddles and bakes. The rotation may make potash available, but it cannot add potash.

THE PHOSPHORIC ACID

The questions presenting themselves in connection with phosphoric acid may be interesting, but are perplexing. Most of our soils are fairly well supplied with it—from 0.10 to 0.18 percent in most soils. A few are richer and many poorer. When the crop is removed from the land, as is often the case with our alfalfa, a great deal of phosphoric acid is lost from the soil. These are practically the rough features of our problems succinctly recapitulated.

The sanitary conditions of the soil we understand to be the suppression of pathogenic fungi or other micro-organisms that have been detrimental to the crops we desired to grow or to an increase of beneficial micro-organisms. This work is entirely beyond our province. The mechanical condition of the soil which is improved refers to its tilth. Of this we have no measure, nor can we specify in what it definitely consists, though aeration and the forming of soil aggregates are certainly parts of it.

The legumes in particular have been considered as increasing the supply of nitrogen by direct addition to it. No stress has been laid upon their indirect effects by improving the sanitary conditions of the soil and thereby permitting a subsequently increased fixation and nitrification of this element to the advantage of succeeding crops.

The potash (K_2O) has not been considered as playing any important and direct part in the benefits produced. Alfalfa plants are very heavy feeders upon this element, a crop of 4½ tons removing more than 213 pounds per acre. This question is not involved, as the nitrogen question is, by any possible increase from the atmosphere or other source. The soil has a fixed potential supply and the question is whether this potential supply can be made an actual one rapidly enough to meet the demands of succeeding crops in such measure as to give an increase.

We do not know the optimum ratio between the total available supply and the requirements of a maximum crop, other conditions being more favorable than the minimum limiting condition. One of the general properties of soils is a power to remove potash from solutions enabling them to prevent the removal of this element from the soil by moving water but not to prevent plants from obtaining it. In connection with this property, perhaps only another feature of it, is the exchange of soda or lime for the potash that it takes up. We may explain by this property the fact that our drain waters contain principally calcic and magnesic sulfates and sodic carbonate with only a little potash salts of any kind. This statement applies in general to our return waters. The local reader must bear in mind that while the general facts applying may be universal, the semi-arid conditions of Colorado present a very marked case in which we have an accumulation of soluble salts. Our irrigating is confined to the growing season of our crops and is aimed to supply them with only the necessary amount of moisture for their development, including the seasonal rainfall which is in the total only light, or we would not have a semi-arid condition. For the greater part of the year there is not moisture enough to move the products of the weathering of the soil particles to any considerable distance downward in the soil. There is very little of our soil that, under favorable conditions, fails to show the efflorescence of white salts, designated as white alkali, which moves up and down in the soil and may move entirely out of it, but the potash involved in the changes is prevented by the soil itself from participating freely in these

movements, so it happens that the efflorescences contain sulfates of lime, magnesia and soda principally, but occasionally small amounts of potash up to perhaps 3.5 percent calculated as sulfates, and the drain waters, calcic and magnesic sulfates and sodic carbonate sometimes with a little potash. The ground waters are usually intermediate in the composition of the salts held in solution, but even these carry only small amounts of potash. These salts participate only slightly in the movements of the salts in the soil, being held in loose combination by the soil particles, and are available to the plants.

We have stated the potential supply or the total potash in our soils to constitute from 2.25 to 2.5 percent of their weight. We have also referred to the process of weathering whereby the so-called alkalis, among which potash is seldom present, are produced. We have also stated that the potash with which plant growth or crop production is concerned is held in some kind of combination by the soil particles. None of these statements intimates that the potash in the soil takes no part in the changes produced by weathering or decomposition. In Part I, Section II, of this bulletin we have set forth that this is not the case, but on the contrary that it is the element most largely involved in these changes. We shall come back to this subject.

The phosphoric acid, like the potash, is, for a given soil, a quantity that may be diminished but not increased by any system of rotation. There are questions of its availability. If a rotation of crops improves this condition of crop production it must be by enabling the succeeding crop to obtain more readily the amounts needed by it. I do not recall having seen any statements concerning the manner of action of any crop on this factor. The solubility of the various forms of phosphoric acid or its salts in the soil has been discussed by very many writers. Our soils everywhere contain soluble salts, principally sulfates, but also carbonates. Our ground and drain waters contain sodic carbonate; our river waters within their mountain sections, carbonates of lime, magnesia, potash and soda.

PHOSPHORIC ACID IN SOIL SUFFICIENT

Our soils are nowhere deficient in calcium. On the contrary, it is common for them to carry from 1.5 to 6.5 or more percent of calcic carbonate, occasionally sulfate, even in great excess. The deportment of the phosphates in our soils has not been made out. Our observations on the effects of phosphates applied to the soil have not been in accord with those observed

elsewhere and we have no explanation to offer for the fact. The explanation cannot be formulated to the effect that we have an abundance of phosphoric acid in our soil. If we have, the standards adopted as criteria in this matter do not apply in our case. This may be true. I recall having seen the statement that plants could satisfy their needs for phosphoric acid from a solution carrying no more than 1 part per million, but the general notion concerning the amount in an ordinarily productive soil is, for the lowest limit, 500 parts per million and 1,000 parts for a medicum. We have applied super-phosphate to soils showing the lower limit or scarcely more than this with no advantage whatever. The only conclusion that we could draw was the very evident one, that the quantity present in the soil was sufficient, whether it was in accord with the dicta of the authorities or not. Perhaps the claim that very dilute solutions of phosphates are sufficient to satisfy the demands of plants, may be nearer the truth than the limits given. It is certain that the application of 15 p. p. m. of soluble phosphorus, 34.5 p. p. m. of phosphoric acid, to the soil with which we have experimented in this study, produced no increase of crop and produced no effect upon its date of maturing, or its quality.

PLANTS PREPARE THEIR OWN FOOD

There remains another consideration, to wit; the action of the rotation crop through its own activities in bringing about new conditions. An old explanation of how crops feed was that they excreted substances, acids, that attacked the soil particles and brought the food elements into solution. We have for a long time assumed that a 1 percent solution of citric acid imitated this action quite well. This would appear to be an arrangement for the supply of the plant's necessities, but would not offer any explanation of the decided benefits accruing to succeeding crops, which is the question with which we are concerned, unless the acid excreted brought more of the specific plant foods into solution than could be used by the plant in question.

The etching figures on a polished surface of limestone are accepted as proof of these acid excretions, but whether they are other than an aqueous solution of carbon dioxid is still in doubt so far as I know. Whether there be any other acid excreted by the roots or not, we are fully justified, as shown in Part I of this bulletin, in stating that carbon dioxid is given off by the roots in large quantities, sufficient to maintain a quantity equal to upwards of 1 percent, 1.5 to 1.7 percent, of the soil atmosphere, notwithstanding the lively diffusion of this gas

from the surface of the soil. This was shown by experiments made in 1921, 1922 and 1923. The atmosphere at 6.5 feet above the surface contained approximately 0.04 percent, while that at the surface of the fallow ground, but under a covering of two thicknesses of canvas, was approximately 0.15 percent, or four times as much.

PRELIMINARY OBSERVATIONS ON CARBON DIOXID

Part I presented the results of a preliminary series of observations on the development of carbon dioxid in the soil at different depths in fallow ground for three seasons and in cropped land for two seasons. The fallow land was not irrigated; the cropped land was irrigated. The record of temperature and rainfall was obtained from the station record. The second section of Part I presents a study of the action of carbon dioxid and water on felspar, with a few experiments to show its action on the soil and subsoil, which are highly calcareous. This discussion was presented because of the fundamental importance of the facts.

SCOPE OF THIS WORK

Part I presents only the fallow and the effects of clover and mixed grasses on the soil atmosphere. We shall in this part extend these observations to the effects of alfalfa, wheat and corn and also include clover and fallow. Further we shall present an extended series of total and nitric nitrogen determinations, a study of the exchange values of the soil, the effect of the rotation upon the water-soluble potash in the soil, and a brief study of the deportment of the soil after the crops have been plowed under and the soil cultivated fallow. The points that we shall try to present will be the study of the amount of carbon dioxid developed in these plots and the duration of the effects of the crop in this regard; also the amount of nitrogen, total and nitric, for a short period. We shall further endeavor to present the effects of these crops upon the fixing and nitrifying capacity of the soil. While we lay stress upon the effects of this rotation on the relations of these crops to the soil nitrogen, we shall also present the effects upon the amount of potash soluble in water.

SANITARY CONDITIONS OF SOIL

While we believe the sanitary and mechanical conditions of the soil to be of primary importance, we cannot present any study of these features except as they may be indicated by the

effects of the rotation in the fixing and nitrifying power of the soil. Beyond this we shall be compelled to confine ourselves largely to purely chemical considerations, which, in fact, are inadequate.

CONVENTIONAL TO CONSIDER NITROGEN FIRST

In this connection it certainly will be conventional to give nitrogen the first place, though it presents many difficulties. It is not unvarying in its quantity present in the soil; on the contrary, it is constantly being added to and removed from the soil. Further, it is a question in what form plants take it from the soil, but in the main there is only one form to be considered and that is nitric acid or nitrates. Whatever nitrogen may be present in the soil, its significance is simply an indication of the possible supply of nitrates by its conversion into these salts which are not at all permanent in the soil. They may be used up almost completely by growing crops, by the soil flora, or they may be removed by water.

In our experiments we have not used land that has been heavily manured in the past, nor such as is rich in humus, which might enrich the soil in comparatively stable forms of nitrogen. The nitrogen in our soils seems to be very reactive and subject to rapid variations. Its distribution is so capricious that it is very difficult, almost impossible, to be sure that a sample taken in a field is really representative. At one time I took 150 samples from a block of land 5 by 30 feet, or a 1-foot core from the center of each square foot. The minimum found was 0.11016 percent and the maximum 0.1455 percent. The difference is 0.0354 percent and occurred in 2 adjacent square feet. The average total nitrogen found in other samples of this field is 0.1448 percent, very nearly the same as that found as the maximum in our 150 samples whose average is 0.12631 percent. The history of the particular plot sampled should be known before too much confidence should be entertained in using the results in judging of changes even in adjoining land.

ALFALFA AND NITROGEN

In an attempt to form a definite estimate in regard to the effects of alfalfa upon the nitrogen content of the land occupied by it, we were compelled to choose a piece of land that had been in alfalfa for 4 years and before that had been used as a pasture or rather a run for horses. While this land is separated from that just discussed by only some 300 feet, it is different soil and has a different past. It, however, was the best available.

This was sampled systematically throughout the season of 1926 on 53 different dates. The first foot was taken in 2 samples, each 6 inches. The average of these is 0.1327 percent for the total nitrogen. This is only a little higher than the average found for our 150 samples, i. e., 0.1263, and is a little lower than the average of general samples from the adjoining land. We cannot obviate this weakness in our data, but we believe it to be no more serious than the variations found in different sets of samples taken from this field itself. It is unfortunate that we have no analyses giving the nitrogen content of this soil 5 and 6 years ago. They would make our data much more satisfactory. As it is the data show the present state of affairs and we can only assume that it was formerly not unlike the rest of the land, which I believe to be correct within reasonable limits. These statements relate to the total nitrogen and have no reference to the nitric nitrogen and would have no value if they were intended to refer to it.

The portion of the alfalfa field sampled was about 2 acres in size which was sampled in 5 lines, 3 parallel to its shorter side and 2 diagonals. A core was taken in each line every 10 paces, approximately 30 feet apart, and 8 cores were united to form a sample. Fifty-three sets were taken to the depth of 1 foot and 7 sets to a depth of 6 feet.

WHAT OUR SAMPLES REPRESENT

It is unfortunate, as already intimated, that this whole set of samples represents nothing more than the facts obtaining in this soil during the season of 1926, after the land had been in alfalfa for 4 years, preceded by pasturing or use as a run for horses for several years, possibly 12 or even 15 years. We do not know what the supply of total nitrogen was previous to laying it down to alfalfa, and for reasons already given we cannot compare it with any other plot in this respect. These data do show, however, the amount and distribution of both the total and nitric nitrogen in this soil after its being in alfalfa for 4 years, for each successive 6 inches to a depth of 6 feet with a separate sample representing the loose soil and plant debris scraped off the surface of the soil.

We here give the averages obtained for the total nitrogen in adjacent land sampled to a depth of 1 foot. This land is level and is all of the same type and, from a general standpoint, of the same character. General samples of this soil taken over a period of several years is 0.1558 percent, to a depth of 1 foot; for 150 samples taken on same date, 0.1263, and for the 53 sam-

ples taken for this field that had been in alfalfa for 4 years it is 0.1327 percent.

It has been stated that the data given for total nitrogen apply only indirectly to the nitric nitrogen which is the form taken up by plants and the nitrogen designated as total must be changed to this form before it has any value as a plant food. This change in the soil is accomplished by certain organisms and the total nitrogen is only a potential supply for the plants. This change is accomplished rapidly in some soils and more slowly in others; besides all nitrogen is not equally easily nitrifiable.

The amount actually available at any time during the growth of the crop will depend upon the efficiency of the soil to effect this change. These nitrates are easily soluble in water and therefore available to the plants; further, the soil aggregates have little or no power to retain them and therefore water may, if sufficient in quantity to cause drainage, move them downward and even out of the soil.

CROPS AND NITRIFICATION

It is also claimed that some plants favor the growth and activity or efficiency of these organisms while others are antagonistic to them and so tend to prevent the formation of nitrates. Grasses in general are supposed to sustain the latter relation to them. All growing plants tend to reduce the amount of nitrates in the soil by using them up. This, in some cases, applies to the micro-organisms as well as to our cultivated crops. The amount of nitrates found at any time under any crop is simply the amount that survives appropriation by the crop and other losses. If its formation has been prevented by the growing crop, as is claimed to be the case in some instances, another problem is presented.

There may be very considerable differences in the amounts of these salts present in the same land occupied by growing plants and free from them. In short stretches of rows where no stand has been obtained the nitrates are apt to be high; for instance, in a fallow spot in a beet field, in samples taken between the rows, we got 28 p. p. m. nitric nitrogen, equivalent to 168 pounds of sodic nitrate per million of soil, or in this case in the top 3 inches of the soil; whereas we found between the beets in the row from 0.75 to 5 p. p. m., the latter amount being equal to 30 pounds of sodic nitrate in the same amount of soil. But in our alley between the beet plots we obtained 35 p. p. m., equivalent to 210 pounds of sodic nitrate. These facts justify us in using great caution in interpreting the results obtained unless we are acquainted with the cultural history of the sample and its local conditions as well.

RECORD OF THIS LAND SINCE 1919

The cultural treatment of this land since 1919 as furnished by Dr. Robertson of the department of agronomy is as follows:

1920	Summer fallow.
1921	Winter rye.
1922	Clover.
1923	Spring wheat.
1924	Spring wheat.
1925	Began our experiments.
1926	Continued them.
1927	Plowed under crops, also plowed fallow 23 September.
1928	Part of land planted to spring wheat and observations on fixation, nitrification and soluble potassium continued.

The following tables give the total and nitric nitrogen in a 4-year-old alfalfa field, and in Section 300, a fallow after 2 years in wheat; also in Section 100, contemporary observations on fallow and alfalfa plots.

TABLE 1.—Total Nitrogen and Nitric Nitrogen in Soil of a 4-year-old Alfalfa Field. Top 6 inches. Season 1926*.

Date	Total Percent	Nitric p.p.m.	Date	Total Percent	Nitric p.p.m.
	A**			D	
19 Apr.	0.1484	1.0		NW to SE	
10 May	0.1266	8.0	4 May	0.1596	3.0
1 June	0.1526	3.0	19 May	0.1393	6.0
7 June	0.1456	4.0	12 June	0.1519	4.0
10 July	0.1589	11.0	3 July	0.1631	9.0
24 July	0.1505	9.0	19 July	0.1456	7.0
9 Aug.	0.1526	13.0	4 Aug.	0.1589	10.0
21 Aug.	0.1491	6.0	16 Aug.	0.1638	10.0
9 Oct.	0.1582	9.0	2 Oct.	0.1645	9.0
15 Nov.	0.1547	6.0	27 Oct.	0.1657	10.0
			1 Dec.	0.1582	6.0
Average	.1507		Average	.1571	

Date	Total Percent	Nitric p.p.m.	Date	Total Percent	Nitric p.p.m.
	B			E	
27 Apr.	0.1498	6.0		NE to SW	
13 May	0.1491	6.0	24 May	0.1610	5.0
5 June	0.1680	3.0	15 June	0.1490	4.0
26 June	0.1778	7.0	23 June	0.1568	5.0
14 July	0.1757	8.0	7 July	0.1673	8.0
28 July	0.1638	10.0	22 July	0.1540	6.0
11 Aug.	0.1617	12.0	7 Aug.	0.1540	8.0
25 Aug.	0.1792	6.0	18 Aug.	0.1561	—
23 Sept.	0.1484	4.0	18 Sept.	0.1624	6.0
12 Oct.	0.1617	5.0	6 Oct.	0.1680	5.0
19 Nov.	0.1638	6.0	9 Nov.	0.1624	3.0
			4 Dec.	0.1624	6.0
Average	.1608		Average	.1589	

Date	Total Percent	Nitric p.p.m.
	C	
30 Apr.	0.1505	6.0
18 May	0.1561	3.0
9 June	0.1498	4.0
30 June	0.1477	6.0
16 July	0.1491	6.0
31 July	0.1526	9.0
14 Aug.	0.1470	10.0
28 Aug.	0.1876	5.0
29 Sept.	0.1533	7.0
16 Oct.	0.1582	5.0
26 Nov.	0.1568	6.0
Average	.1553	

* All samples were taken and determinations made by Mr. Vail. The average for all the 6-inch samples is: Total nitrogen 0.1566 percent (0.1266—0.1792, diff. 0.0526 percent); for the nitric nitrogen the average is 7.0 p. p. m.

** Letters A, B, C, D and E indicate lines of sampling.

TABLE 2.—Total Nitrogen and Nitric Nitrogen in Soil of a 4-year-old Alfalfa Field, 7 to 12 inches. Season of 1926.

Date	Total Percent	Nitric p.p.m.	Date	Total Percent	Nitric p.p.m.
	A			D	
19 Apr.	0.1085	3.0	4 May	0.0980	1.0
10 May	0.0980	3.0	19 May	0.1050	3.0
1 June	0.1078	2.0	15 June	0.0994	2.0
17 June	0.1029	2.0	3 July	0.1078	4.0
10 July	0.1071	6.0	19 July	0.1001	3.0
24 July	0.1064	3.0	4 Aug.	0.1155	3.0
9 Aug.	0.1071	5.0	16 Aug.	0.1148	4.0
21 Aug.	0.1057	3.0	2 Oct.	0.1120	4.0
9 Oct.	0.1141	3.0	27 Oct.	0.1134	3.0
15 Nov.	0.1036	4.0	1 Dec.	0.1085	4.0

Date	Total Percent	Nitric p.p.m.	Date	Total Percent	Nitric p.p.m.
	B			E	
27 Apr.	0.1057	3.0	29 May	0.1120	3.0
13 May	0.1015	3.0	15 June	0.0980	2.0
5 June	0.1169	3.0	23 June	0.1113	3.0
26 June	0.1099	3.0	7 July	0.1029	3.0
4 July	0.1232	3.0	22 July	0.1064	3.0
28 July	0.1071	3.0	7 Aug.	0.1064	3.0
1 Aug.	0.1106	3.0	18 Aug.	0.1043	6.0
25 Auv.	0.1162	4.0	18 Sept.	0.1120	3.0
23 Sept.	0.1218	3.0	6 Oct.	0.1127	2.0
12 Oct.	0.1008	3.0	9 Nov.	0.1042	3.0
19 Nov.	0.1127	4.0	4 Dec.	0.1078	4.0

Date	Total Percent	Nitric p.p.m.
	C	
30 Apr.	0.1092	3.0
18 May	0.1092	3.0
9 June	0.1064	2.0
30 June	0.1015	3.0
16 July	0.0959	3.0
31 July	0.1064	3.0
14 Aug.	0.1043	3.0
28 Aug.	0.1134	2.0
29 Sept.	0.1029	3.0
16 Oct.	0.1106	3.0
26 Nov.	0.1106	4.0

The average for all samples 7 to 12 inches is: Total nitrogen, 0.1077 percent; nitric nitrogen, 2.0 p. p. m.

TABLE 3.—Total Nitrogen and Nitric Nitrogen in Soil of a 4-year-old Alfalfa Field. Season of 1926.

6-Inch Sections to a Depth of 72 Inches.

Date	19 May		23 June		22 July		21 Aug.	
Depth Inches	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Tòtal Percent	Nitric p.p.m.
*Surface	0.1820	11.0	0.1876	—	0.2097	18.0	0.1946	15.0
0- 6	0.1393	6.0	0.1568	5.0	0.1540	6.0	0.1582	9.0
7-12	0.1050	3.0	0.1113	3.0	0.1064	3.0	0.1059	3.0
13-18	0.0644	2.0	0.1714	2.0	0.0672	2.0	0.0623	2.0
19-24	0.0467	2.0	0.0378	2.0	0.0483	2.0	0.0448	2.0
25-30	0.0203	1.0	0.0385	2.0	0.0357	2.0	0.0336	1.0
31-36	0.0280	1.0	0.0301	2.0	0.0294	2.0	0.0280	1.0
37-42	0.0238	1.0	0.0294	2.0	0.0266	2.0	0.0322	1.0
43-48	0.0238	1.0	0.0322	1.0	0.0257	1.0	0.0294	2.0
49-54			0.0315	1.0	0.0301	2.0	0.0322	2.0
55-60			0.0336	2.0	0.0287	1.0	0.0308	1.0
61-66			0.0294	2.0	0.0259	2.0	0.0294	2.0
67-72			0.0336	1.0	0.0308	1.0	0.0322	2.0

Date	23 Sept.		27 Oct.		26 Nov.	
Depth Inches	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.
*Surface	0.2457	4.0	0.2261	27.0	0.2149	29.0
0- 6	0.1484	4.0	0.1657	10.0	0.1568	6.0
7-12	0.1218	3.0	0.1134	3.0	0.1166	4.0
13-18	0.0812	2.0	0.0616	3.0	0.0714	2.0
19-24	0.0532	2.0	0.0469	1.0	0.0511	2.0
25-30	0.0392	1.0	0.0357	1.0	0.0399	2.0
31-36	0.0371	1.0	0.0294	1.0	0.0329	1.0
37-42	0.0280	1.0	0.0259	2.0	0.0266	1.0
43-48	0.0287	1.0	0.0238	1.0	0.0259	2.0
49-54	0.0280	1.0	0.0224	1.0	0.0266	2.0
55-60	0.0294	1.0	0.0266	1.0	0.0252	1.0
61-66	0.0273	1.0	0.0245	1.0	0.0259	1.0
67-72	0.0308	1.0	0.0252	1.0	0.0306	2.0

*Surface means loose material, soil and plant debris that could be taken up with the hand.

TABLE 4.—Total Nitrogen and Nitric Nitrogen to the Depth of 6 Inches, Section No. 300 of the Experiment Station Plots. Fallow in 1926.

Date	Total Percent	Nitric p. p. m.	Date	Total Percent	Nitric p. p. m.
	A			D	
19 Apr.	0.1022	3.0	19 May	0.1085	6.0
4 May	0.1120	3.0	9 June	0.1134	8.0
24 May	0.1127	5.0	22 June	0.1106	8.0
15 June	0.1071	7.0	14 July	0.1127	11.0
3 July	0.1041	6.0	28 July	0.1092	12.0
19 July	0.1064	11.0	11 Aug.	0.1071	11.0
4 Aug.	0.1169	13.0	25 Aug.	0.1134	15.0
16 Aug.	0.1113	14.0	2 Oct.	0.1148	14.0
18 Sept.	0.1113	12.0	26 Oct.	0.1134	19.0
9 Oct.	0.1071	16.0	1 Dec.	0.1120	17.0
15 Nov.	0.1092	11.0			
Average	.1093				

Date	Total Percent	Nitric p. p. m.	Date	Total Percent	Nitric p. p. m.
	B			E	
27 Apr.	0.1057	3.0	18 May	0.1155	6.0
10 May	0.1092	4.0	12 June	0.1127	9.0
1 June	0.1008	5.0	30 June	0.1064	10.0
17 June	0.1120	8.0	16 July	0.1148	11.0
7 July	0.1127	9.0	31 July	0.1169	20.0
21 July	0.1085	14.0	14 Aug.	0.1141	13.0
7 Aug.	0.1127	11.0	28 Aug.	0.1176	15.0
18 Aug.	0.1092	16.0	6 Oct.	0.1190	15.0
22 Sept.	0.1134	14.0	9 Nov.	0.1120	9.0
12 Oct.	0.1155	22.0	4 Dec.	0.1099	17.0
19 Nov.	0.1064	18.0			
Average	.1097				

Date	Total Percent	Nitric p. p. m.
	C	
30 Apr.	0.1036	4.0
13 May	0.1085	4.0
5 June	0.1162	6.0
26 June	0.1092	9.0
10 July	0.1078	13.0
24 July	0.1120	11.0
9 Aug.	0.1134	16.0
20 Aug.	0.1106	14.0
29 Sept.	0.1155	14.0
16 Oct.	0.1127	16.0
24 Nov.	0.1127	18.0
Average	.1111	

The average for all samples 0 to 6 inches is: Total nitrogen, 0.1110 percent; nitric nitrogen, 11.0 p. p. m.

A, B, C, D and E have the same relation to the plot as in the preceding tables.

TABLE 5. Total Nitrogen and Nitric Nitrogen from 7-12 Inches, Section No. 300, Experiment Station Plots. Fallow in 1926.

Date	Total Percent	Nitric p. p. m.	Date	Total Percent	Nitric p. p. m.
	A			D	
19 Apr.	0.0987	3.0	19 May	0.0952	5.0
4 May	0.1042	2.0	9 June	0.0957	6.0
24 May	0.0952	4.0	22 June	0.1001	7.0
15 June	0.1071	7.0	14 July	0.0924	7.0
3 July	0.0896	6.0	28 July	0.0994	8.0
19 July	0.0868	8.0	11 Aug.	0.0994	6.0
4 Aug.	0.0910	7.0	25 Aug.	0.1008	8.0
16 Aug.	0.0931	7.0	2 Oct.	0.0959	9.0
18 Sept.	0.0966	7.0	26 Oct.	0.0959	9.0
9 Oct.	0.0931	8.0	1 Dec.	0.0952	17.0
15 Nov.	0.0952	11.0			
Average	0.0866				

Date	Total Percent	Nitric p. p. m.	Date	Total Percent	Nitric p. p. m.
	B			E	
27 Apr.	———	3.0	18 May	0.0973	6.0
10 May	0.0819	4.0	12 June	0.1001	7.0
1 June	0.1015	5.0	30 June	0.1008	8.0
17 June	0.1022	9.0	16 July	0.1022	7.0
7 July	0.0994	7.0	31 July	0.1001	11.0
21 July	0.0994	10.0	14 Aug.	0.1001	8.0
7 Aug.	0.1008	8.0	28 Aug.	0.0973	7.0
18 Aug.	0.0959	10.0	6 Oct.	0.1015	7.0
22 Sept.	0.0966	7.0	9 Nov.	0.0966	10.0
12 Oct.	0.0924	8.0	4 Dec.	0.0945	14.0
19 Nov.	0.0959	13.0			
Average	0.0966				

Date	Total Percent	Nitric p. p. m.
	C	
30 Apr.	0.1001	5.0
13 May	0.0924	5.0
5 June	0.1008	5.0
26 June	0.1001	7.0
10 July	0.0945	8.0
24 July	0.1029	8.0
9 Aug.	0.1001	10.0
20 Aug.	0.0980	10.0
29 Sept.	0.0966	7.0
26 Oct.	0.0952	8.0
24 Nov.	0.1015	16.0
Average	0.1002	

The average for all samples taken 7 to 12 inches is: Total nitrogen, 0.0982 percent; nitric nitrogen, 8.0 p. p. m.

TABLE 6.—Total Nitrogen and Nitric Nitrogen in Section No. 300. Fallow in 1926.

6-inch sections to a depth of 6 feet.

Date	19 May		22 June		27 July		20 Aug	
Depth Inches	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.
Surface	0.1134	3.0	0.1008	8.0	0.1106	8.0	0.1120	5.0
0- 6	0.1085	6.0	0.1106	8.0	0.1085	14.0	0.1106	14.0
7-12	0.0952	5.0	0.1001	7.0	0.0994	10.0	0.0980	10.0
13-18	0.0672	5.0	0.0707	4.0	0.0658	5.0	0.0546	6.0
19-24	0.0455	6.0	0.0511	6.0	0.0511	5.0	0.0504	6.0
25-30	0.0371	8.0	0.0413	8.0	0.0378	7.0	0.0378	7.0
31-36	0.0287	9.0	0.0294	11.0	0.0308	10.0	0.0322	8.0
37-42	0.0294	9.0	0.0287	10.0	0.0294	11.0	0.0301	9.0
43-48	0.0294	8.0	0.0315	9.0	0.0266	10.0	0.0266	7.0
49-54			0.0280	7.0	0.0238	8.0	0.0231	5.0
55-60			0.0252	6.0	0.0273	6.0	0.0257	4.0
61-66			0.0252	7.0	0.0245	6.0	0.0233	5.0
67-72			0.0273	7.0	0.0266	6.0	0.0252	5.0

Date	23 Sept		26 Oct.		24 Nov.	
Depth Inches	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.
Surface	0.1106	6.0	0.1099	8.0	0.1155	6.0
0- 6	0.1113	14.0	0.1134	19.0	0.1127	18.0
7-12	0.1001	10.0	0.0959	9.0	0.1015	16.0
13-18	0.0644	7.0	0.0707	6.0	0.0665	8.0
19-24	0.0518	7.0	0.0518	6.0	0.0539	8.0
25-30	0.0399	8.0	0.0392	7.0	0.0427	9.0
31-36	0.0336	9.0	0.0322	8.0	0.0322	11.0
37-42	0.0350	10.0	0.0287	10.0	0.0280	10.0
43-48	0.0280	9.0	0.0252	11.0	0.0252	9.0
49-54	0.0266	9.0	0.0245	8.0	0.0224	7.0
55-60	0.0273	8.0	0.0231	5.0	0.0231	6.0
61-66	0.0252	6.0	0.0245	6.0	0.0224	5.0
67-72	0.0266	6.0	0.0252	6.0	0.0210	5.0

TABLE 7.—Total Nitrogen and Nitric Nitrogen in Section No. 300, to a Depth of 10 Feet. Samples, 7 December, 1926.

	Total Percent	Nitric p.p.m.
First foot	0.1057	17.0
Second foot	0.0560	6.0
Third foot	0.0341	12.0
Fourth foot	0.0280	13.0
Fifth foot	0.0210	10.0
Sixth foot	0.0252	7.0
Seventh foot	0.0308	8.0
Eighth foot	0.0315	9.0
Ninth foot	0.0350	11.0
Tenth foot	0.0336	10.0

TABLE 8.—Total Nitrogen and Nitric Nitrogen in Fallow and Alfalfa Plots, Section No. 100. Season 1926.

	*FALLOW			
	0 to 6 Inches		7 to 12 Inches	
Date	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.
21 May	0.1400	7.0	0.1197	8.0
19 June	0.1302	11.0	0.1134	10.0
29 June	0.1302	12.0	0.1085	8.0
26 July	0.1351	11.0	0.1134	7.0
27 Aug.	0.1344	12.0	0.1169	8.0
25 Sept.	0.1337	14.0	0.1120	6.0
14 Oct.	0.1183	12.0	0.1008	3.0
10 Nov.	0.1288	15.0	0.1092	10.0
Average	0.1313	12.0	0.1117	8.0

	ALFALFA			
	0 to 6 Inches		7 to 12 Inches	
Date	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.
21 May	0.1506	2.0	0.1051	1.0
19 June	0.1442	6.0	0.1176	4.0
29 June	0.1428	8.0	0.1169	5.0
26 July	0.1414	7.0	0.1169	3.0
27 Aug.	0.1603	9.0	0.1260	3.0
25 Sept.	0.1407	7.0	0.1155	3.0
14 Oct.	0.1435	6.0	0.1253	2.0
10 Nov.	0.1414	4.0	0.1176	3.0
Average	0.1456	6.1	0.1176	3.0

*There were two plots fallow and two in alfalfa; four cores were taken from each plot and the eight cores were united to form composites for fallow and alfalfa, respectively.

TABLE 9.—Total Nitrogen and Nitric Nitrogen in Fallow and Alfalfa Plots, Section No. 100. Season 1926.

6-inch sections to a depth of 6 feet.

	FALLOW				ALFALFA			
Date	21 May		15 Oct.		21 May		15 Oct.*	
Depth Inches	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.	Total Percent	Nitric p.p.m.
Surface	0.1484	16.0	———	———	0.1750	8.0	———	———
Surface	0.1576	11.0	0.1477	15.0	0.1922	33.0	0.2163	37.0
0- 6	0.1400	7.0	0.1183	12.0	0.1506	2.0	0.1435	6.0
7-12	0.1197	9.0	0.1008	3.0	0.1051	1.0	0.1253	2.0
13-18	0.0714	12.0	0.0747	3.0	0.0875	2.0	0.0770	2.0
19-24	0.0525	13.0	0.0588	5.0	0.0609	1.0	0.0588	2.0
25-30	0.0406	12.0	0.0462	2.0	0.0476	1.0	0.0476	1.0
31-36	0.0357	9.0	0.0413	1.0	0.0366	3.0	0.0385	1.0
37-42	0.0315	8.0	0.0357	8.0	0.0364	3.0	0.0336	1.0
43-48	0.0280	6.0	0.0364	8.0	0.0322	1.0	0.0315	1.0
49-54	———	———	0.0350	8.0	———	———	0.0287	1.0
55-60	———	———	0.0287	4.0	———	———	0.0252	1.0
61-66	———	———	0.0257	6.0	———	———	0.0259	1.0
67-72	———	———	0.0259	5.0	———	———	0.0245	2.0

* Soil too dry.

It appears from these tables that from 18 or 30 inches downward the total nitrogen is not abundant and varies but little; from 18 to 30 inches there is less than 0.05 percent and from this point on between 0.02 and 0.04 percent. The top 18 inches, especially the top 6 inches, of the land in alfalfa are richer in nitrogen than the fallow. On the other hand, the fallow is much richer in nitric nitrogen than the alfalfa land, which is true to the depth of 72 inches.

We believe that nitric nitrogen is essentially the only form available to plants. Its distribution to the depth of 6 feet is not uncommon, according to our observations, but it is rather more uniform in these samples than we have heretofore found to be the case. This evidently depends upon the amount of water, rain and irrigation water, that percolates through the soil.

The nitric nitrogen is available to the plants, but the total nitrogen must first be transformed into nitric nitrogen. The rate at which this change takes place in the soil is an important factor. This particular soil possesses a high nitrifying efficiency. How this efficiency is affected by such crops as wheat and alfalfa has not been studied, but others, Lyon and Bizzell, of the New York Experiment Station, have shown that some plants, rye and timothy, depress this activity in the soil. In the land planted to alfalfa only that portion which may be scraped off the surface with the hand contains much of this form of nitrogen; either the alfalfa appropriates it readily or prevents its formation; it may do both.

Distribution of Nitrogen in Our Plots

The surface 6 inches in the alfalfa hay field contained 0.0456 percent more nitrogen than a like depth of Section No. 300 and the second 6 inches, 0.0095 percent more, but from this depth, 1 foot, to that of 6 feet, the differences are small and sometimes in favor of the fallow, five times out of eleven. We find the same relation in Section 100, in which case the fallow and the alfalfa land have the same previous history. This, as is elsewhere stated, is not the case with the alfalfa hay field and Section 300. The difference in the top 6 inches of the respective plots in Section 100 is 0.0143 in favor of the alfalfa or 286 pounds of nitrogen in this top 6 inches per acre, the average of eight samplings. This difference may be due to the alfalfa, as the plots have the same history and each was sampled eight times and eight cores were united to form a single sample. This ought to eliminate the accidents arising from the difficulties in sampling.

This is the condition at the end of the season. There was a difference of 0.0106 percent in favor of the alfalfa plots at the beginning. On the 10th of November, the last date of sampling for the season, there was a difference of 0.0126 percent. The average difference in favor of the top 6 inches of the alfalfa soil for the whole season was 0.0143 percent or 286 pounds of nitrogen per acre to this depth. In our general statement we attribute the whole of this to the alfalfa, but it is clear that this is doubtful, as there was a difference of .0106 percent, 212 pounds to the acre, to this depth in favor of the alfalfa plots to begin with, so if we deduct this there remains but 74 pounds per acre. This is too small an amount upon which to predicate an increase even though the samples were composites and taken with care and the nitrogen determinations done in duplicate.

The nitric nitrogen is much more abundant in the fallow than in the alfalfa, from one and a half to four times as abundant. This is especially the case at depths greater than 6 inches.

We can scarcely compare the alfalfa hay field and Section 300 of the station plots, though they are only about 300 feet from one another in a piece of level land. The alfalfa was 4 years old and the field had been used previously as a horse run during which time I do not know whether it was in any crop. Section 300 had been cropped to wheat or other grain 2 years out of 3 for the previous 6 years and was fallow in 1926, when we sampled it to see what results we would get. We regret that they are not comparable.

The alfalfa hay field contains more nitrogen than the fallow, but whether this is due to the history of the land or to the alfalfa is not shown. Had we known 6 or 8 years before we began these experiments that we would use this field and that it would be an alfalfa hay field we would have made records of the nitrogen in it and our later results would have been of greater value. The data pertaining to this field, after having been used as a pasture and then laid down to alfalfa for 4 years, show only that it is richer in nitrogen than another section lying about 300 feet to the east of it, which has been cropped to grain 2 out of 3 years since 1920 and was fallow in 1926.

Even in this alfalfa field the samples taken on the line A carry less nitrogen than those taken on line B, by 0.0101 percent, which shows that some of the variation in nitrogen is not due to alfalfa. This variation, 0.0101 percent, is almost as big as that that we find between the fallow and alfalfa plots of Section 100—0.0106 percent in favor of the alfalfa.

There is more nitric nitrogen in the fallow than under the alfalfa on all dates and depths except in the portion scraped off the surface of the soil and containing actual plant debris, where we found under the alfalfa plants in Section 100, 33 p. p. m. in May and 37 in October, and in the alfalfa hay field we found 27 p. p. m. in October and 29 in November.

Of these four series of samplings, two represent the amounts and distribution of the total and nitric nitrogen in the different plots of about 2 acres each, one fallow during the season of sampling, and the other after a period of 4 years in alfalfa. The other two represent portions of the same plot of land, one kept fallow for 2 years and the other in alfalfa during this time. The difference of the averages for total nitrogen in the last two plots, based on eight samplings of each plot to a depth of 6 inches, is 0.0143 percent. The same for the second 6 inches is 0.0059 percent. The nitric nitrogen in the fallow is uniformly higher than under the alfalfa. This statement applies to the other two pieces of land also.

There is a difference of a few thousandths of 1 percent in the total nitrogen present in favor of the top 6 inches of the alfalfa soil, but this difference falls to less than one-half as much in the second 6 inches, and below 2 feet there is no certain difference between the alfalfa and the fallow. The difference, in favor of the alfalfa hay field, is not more than the equivalent of a dressing of 5 tons of good manure every 4 years. The effects of a 2-year rotation in alfalfa are considered more beneficial than this in whatsoever manner these results may be produced.

Amount and Distribution of Nitrogen in Wheat Land

Similar data have been acquired pertaining to the effects of wheat. Both total and nitric nitrogen were determined in fallow strips, 10 feet wide, between wheat plots and in the plots on the same dates. The strips were not cultivated nor had they been fertilized in recent years. The land had been planted to grain, oats or spring wheat, four successive seasons. The check plots, of course, had received the same treatment and one of these was used for sampling. The average total nitrogen in the plot planted to Fife wheat was in Section No. 1700, samples 3 inches deep, 0.1290; 6 inches, 0.1252; in No. 1900, 3 inches, 0.1273; 6 inches, 0.1286. The first 3 inches of soil were sometimes richer in total nitrogen than the second, but sometimes this was reversed. These averages are based on three samplings made 13 May, 1 September, and 15 October, 1915, which was the fourth successive year that the plots had been planted to grain. The individual samples varied in their nitrogen content

with differences ranging from a few thousandths to a little less than two-hundredths of 1 percent.

On 1 July, 1913, we found in the top 3 inches of Section No. 1700, 0.1285; in Section No. 1800, 0.1190; and in Section No. 1900, 0.1251 percent total nitrogen. It will be noticed that these total-nitrogen determinations differ by a few thousandths only from the averages for the season of 1915, and that three crops have made practically no change in the amount of the total nitrogen.

In 1914, Section No. 1600, which lies just west of No. 1700, was in fallow, while No. 1700 was cropped to wheat. Section No. 1600 was sampled three times and the average of the three sets taken to a depth of 6 inches gave 0.1262 percent total nitrogen, and the average of two sets taken in Section No. 1700 on the same dates that Section No. 1600 was sampled, gave 0.1209 percent.

While the total nitrogen varies from time to time, it does not appear from these data that its amount is materially affected by one or even by three crops of wheat. There are small differences, but one would hesitate to interpret them even though fully persuaded that every reasonable precaution had been taken to avoid errors in sampling and in chemical manipulation. In this work all sampling, preparation and analyses were done in a uniform manner so that our results should be comparable.

The total nitrogen determinations here given are, I judge, really more nearly comparable to those found for the alfalfa hay field, though taken 12 years previously, than are those given for Section 300, because of the lav of the land. Number 300 lies north of Section 1600. The alfalfa hay field lies west of these experimental plots, here designated sections, and overlaps them in its north and south extent. The average total nitrogen in 53 samplings of the top 6 inches of soil in this field is 0.1571. The 6-inch samples from Section 1700 planted to Fife wheat in 1915 gave an average of 0.1289, which leaves a difference of 0.03 percent in favor of the hay field. This includes differences in land and the opposite tendencies of the two crops for 4 years and is too doubtful to be seriously considered.

The fallow in Section 100 showed as the average of eight samplings in 1926, 0.1313 percent total nitrogen to a depth of 6 inches, which is nearly the same as we found in Section 1700 —0.1289 percent in 1915, when it was bearing its fourth consecutive crop of grain (the third one of wheat).

The portion of Section 100 that was planted to alfalfa showed in its second year, 0.1456 percent total nitrogen or an excess of 0.143 percent over the fallow, but the fallow differed by only a little, 0.0024 percent, from the land that had been planted to wheat. Fallow strips between the wheat plots showed an excess over the wheat plots of only 0.0002 percent total nitrogen.

Confusion may arise from the mention of these different plots and the impression be made that they are remote from one another and therefore not comparable. The whole area here considered is less than 10 acres of level land. I do not assert that there are no variations in this soil. I know the contrary to be the fact, but these are less objectionable than the time between the series of experiments, but neither objection could be wholly avoided and the results may be as representative of the facts as any other two series might have been.

THE BENEFICIAL EFFECTS OF ALFALFA CONFINED TO TOP SOIL

Alfalfa increases the total nitrogen in the top 6 inches of soil, while wheat has but little influence either way. The effect of alfalfa on the nitrogen content of the second 6 inches is very small. In the only comparable data that we have, that for the fallow and the alfalfa in Section 100 for the season of 1926, the difference in favor of alfalfa is 0.0048 percent.

It is true of all soil sections that we have studied that the first foot contains approximately twice as much total nitrogen as the second, the second twice as much as the third, but below the third to the depth of 11 feet it is fairly constant, being between 0.02 and 0.03 percent. The total nitrogen includes some nitric nitrogen, but it is relatively only a very small part of the total. The whole of the nitric nitrogen is available, but the rest of the nitrogen must be changed into this form before it is of any use to the plants. How rapidly this change is effected after the fallow and alfalfa is a question which we shall subsequently try to answer.

EFFECTS OF OTHER CROPS

We have endeavored to learn, at least in a tentative way, the effects of some other crops upon the amount of total nitrogen in the soil to a depth of 3 inches. I believe that it would have been better had we divided the top 6 inches in two sections of 3 inches each in every case, for the nearer the surface we came the richer the soil in nitrogen.

In corn we found 0.1275; in sorghum, 0.1244; winter wheat, 0.1197; spring wheat, 0.1333; spring wheat which had been dressed with super phosphate, 0.1456, and spring wheat dressed with potassic chloride, 0.1387 percent. These results show the range of total nitrogen found in our cropped soils, including variations that are independent of the crop then occupying the ground.

NON-NITROGENOUS FERTILIZERS MAY AFFECT AMOUNT OF NITROGEN

The last two percentages given suggest that the fertilization may have had a beneficial influence upon this factor, which we believe to have been the case, and that this influence may be of great importance. While it is scarcely proper to compare the top 3-inch sections with the top 6-inch sections of even the same soil in regard to the total nitrogen contained in them, it may still be considered suggestive that the 3-inch sample planted to wheat and dressed with superphosphate shows 0.1456 percent, while the average of eight 6-inch samplings of soil that had been in alfalfa for two seasons also contained 0.1456 percent of nitrogen. This may be nothing more than a suggestive coincidence; the identity of the figures is certainly only a coincidence, but there remains a suggested fact that fertilization with superphosphate or potassium may cause an increase in the total nitrogen by favoring the development of nitrogen-fixing organisms.

RELATION OF NITRIC NITROGEN DIFFERENT

These relations are altogether different in regard to the nitric nitrogen. In the alfalfa hay field the average amount of nitric nitrogen for 53 samplings to a depth of 6 inches was 7 parts per million. The surface material that could be scraped together with the hands, some of which was of course included in the 6-inch samples, was quite rich in old leaves and remnants of plants and also in nitric nitrogen as well as total nitrogen. Some such samples showed as much as 29 p. p. m. of nitric nitrogen, while the top 6 inches showed 7 p. p. m.; a like number of samplings (53) of the second 6 inches showed only 2 p. p. m. and the rest of the soil to a depth of 6 feet was even poorer in this form of nitrogen.

The same relation holds in the case of the wheat but here we give the sodic nitrate, equivalent to the nitric nitrogen found in the top 4 feet of the soil on different dates. We have taken

the average of two tenth-acre plots planted to different varieties of wheat. This will give us a more generally applicable result than if we had confined ourselves to one plot and one variety of wheat.

These plots had been in wheat the previous year but had been disced and irrigated after the preceding crop had been removed which was about 10 August, 1914, and had been cultivated again in the spring of 1915. The wheat was sown 26 April, 1915.

TABLE 10.—Nitric Nitrogen Given in its Equivalent of Sodic Nitrate in the Top 4 Feet Per Acre. Land Planted to Wheat.

	Pounds		Pounds
13 May, 1914	459.7	28 September	102.0
18 June	120.0	25 October	138.0
8 July	74.4	22 November	171.0
3 August	71.4	13 December	286.0
20 August	100.0	16 February, 1915	196.0
14 September	105.5	22 March	169.0

Spring wheat completes its growing and ripening processes in about 120 days, varying a little from this in different seasons. This wheat was planted in the latter part of April and we found on 13 May the equivalent of 459 pounds of sodic nitrate in the top 4 feet of the soil but this fell rapidly to less than 75 pounds per acre by the time the wheat had ripened. After the crop had been removed, the land irrigated and disced, the nitric nitrogen was restored till on 13 December it had reached the equivalent of 286 pounds of sodic nitrate per acre.

In the alfalfa hay field we found for the season of 1926, 216 pounds; in the alfalfa plot of Section 100, 222 pounds. This compares with the fallow Section 300 with 804 and the fallow Section 100 with 774 pounds.

We do not know the weight of the hay removed from the hay field nor of that removed from the alfalfa plot of Section 100 in 1926, but to credit the hay field with 6000 pounds per acre is very liberal and it is good alfalfa hay that contains 2.2 percent nitrogen. This would give 132 pounds of nitrogen per acre equivalent to 792 pounds of sodic nitrate. As the average amount shown in this soil for the season is 216 pounds, we account for 1008 pounds of sodic nitrate per acre to a depth of 4 feet. This is more by 204 pounds than we find in Section 300 in fallow. This gives us a notion of the amounts of nitrogen or rather its equivalent as sodic nitrate but it does not give us much more because these soils have a different history, i. e., have received different treatment and are not satisfactorily comparable.

In the case of Section 100 we have for the second year in alfalfa an average total nitrogen of 0.0695 percent and in the fallow 0.0645, a difference of 0.0050 percent in favor of the alfalfa. For the nitric nitrogen we have in the alfalfa ground to a depth of 4 feet, the equivalent of 32 pounds of sodic nitrate and in the fallow the equivalent of 45 pounds. There were two alfalfa plots between which lay the fallow.

ARE SMALL PERCENTAGES OF TOTAL NITROGEN SIGNIFICANT?

The difference in the total nitrogen—0.0050 percent—is too small to be accepted as positively due to the alfalfa and at best the value of this amount of total nitrogen, being only one-thirteenth of that present is a question. The thought here had in mind is suggested by the results produced by the application of 19 loads, approximately 35 tons, of good farmyard manure per acre in a wheat experiment. This manure was not distributed through 4 feet of soil but scarcely through more than one-half foot. If we consider it to have contained 1.5 percent nitrogen, there was applied 1050 pounds of nitrogen, approximately 0.0263 percent of the top foot of soil. The effect of this upon the crop was to increase the grain slightly and the straw a little more. There was no effect on the composition of the grain. The application of five times as much nitrogen as the excess we find in favor of the alfalfa over the fallow produced a little increase in the dry matter harvested.

Stated in another way, the significance of small percentages of total nitrogen is doubtful. This in no way applies to the nitric nitrogen. I have never seen any attempt to ascertain the smallest amount of nitrates that will produce effects upon a field crop, but our experience is that it may be disadvantageous, even disastrous to wheat, for instance, to apply 40 pounds of nitric nitrogen per acre at the time of sowing. This amount in our soil is almost exactly equivalent to 10 p. p. m. or 0.0010 percent, reckoned on the top foot. Land in alfalfa shows very little of this form of nitrogen at any depth, only a little more than land planted to spring wheat during the months of June and July, the period of its most active growth, when the nitric nitrogen may be reduced to less than one part per million or 0.0001 percent. This is due probably more to prevention of nitrification than to the complete exhaustion of the nitrates by the plants, for wheat is not an exceedingly heavy feeder of nitrogen and the supply of these nitrates is being constantly renewed by the transformation of organic nitrogen into this form.

A 60-bushel crop of wheat weighing 60 pounds per bushel and with a ratio of 1.5 straw to one of wheat will require about

103 pounds of nitrogen. This amount of nitrogen would be furnished by 6.5 p. p. m. of nitric nitrogen in the soil to a depth of 4 feet, provided it were all used at one time.

We found in the fallow Section 300, 9 p. p. m. to this depth on 21 July, 1926. This land could have furnished all of the nitrogen required by our illustrative crop on this single date with an excess of 2.5 p. p. m. which is more than twice as much as we found under any of our wheat plots in the months of June, July and August. On the other hand, a 4.5-ton crop of alfalfa carries 200 pounds of nitrogen, but the soil to the depth of 4 feet carries more nitric nitrogen than that under the wheat during June and July. There is much less nitric nitrogen under the alfalfa than in the fallow. But according to this statement the alfalfa uses much more nitrogen and leaves more nitric nitrogen in the soil than a wheat crop. This difference is attributable to the root organisms to which alfalfa serves as a host plant.

EFFECT OF RAINFALL

This problem would present itself differently in a country of heavy rainfall, for a sufficiency of water readily moves the nitrates beyond the depth here considered. Our annual rainfall is 14.9 inches; from 6 to 12 inches falls during the growing season of a wheat crop and we apply from 12 to 20 inches according to the season, or such land receives from 30 to 35 inches of water a year. This may cause an irregular distribution of nitrates in the land, but this does not seriously affect the statements made. It, however, raises a question regarding the value of a small increase in the total nitrogen present. This value will depend upon the ease with which the nitrogen may be nitrifiable.

The deportment of the soil in this respect, after occupancy by alfalfa, may be of great importance. We have seen that after wheat the nitrifying power is gradually restored and the recovery of the nitrates goes on for at least 5 months, increasing from 71 pounds in the top 4 feet of the soil on 3 August, to 263 pounds on 13 December. No parallel series of observations has yet been made on land that has been in alfalfa.

The wheat crop does not involve so much nitrogen as alfalfa and it does not materially affect the quantity of total nitrogen but it reduces the nitric nitrogen to a very small quantity, one part or less per million.

FIXATION OF NITROGEN

The nitrifying flora of the soil is probably not more abundant or efficient than that which fixes it, but it is more evident,

for we have no nitrates in the soil which we do not attribute to its action, but we cannot distinguish between the general supply of nitrogen and that due to fixation except by quantitative determinations under controlled conditions, so not much attention has been given to this process aside from the symbiotic fixation attributed to the legumes. It has, however, been demonstrated in our previous studies that this soil has a very pronounced ability in this direction. In one series continued for 27 days, we found from 6 to 10.5 milligrams, an average of 8 milligrams, fixed in each 100 grams of soil. In these experiments the water in the soil was brought up to 17 percent by the addition of ammonia-free water and the samples incubated at 27° C. There is not the least probability that this increase of nitrogen was due to any other cause than the nitrogen-fixing flora of the soil.

In another experiment this soil was put into a clean show-bottle in its field condition, the bottle loosely stoppered and kept at room temperature for the same time, 27 days. In this case we had an increase of 4.8 milligrams of nitrogen for each 100 grams of soil. The former is at the rate of 300 pounds, the latter 192 pounds fixed per acre-foot in less than a month. True, these are experimental results obtained by manipulating small quantities of the soil, 1250 grams in the incubation tests and about 10 pounds of moist soil that were allowed to stand at room temperature. There is no mistake about the increase and it proves that very significant additions of nitrogen may be made to the soil in this way.

This question of fixation under field conditions has arisen previously in connection with other work. We took 3000 pounds of soil from these sections, prepared it and placed it in a bed, arranged to protect it from rain and other accidents and incubated it out of doors for 40 days, adding from time to time enough freshly-distilled ammonia-free water to maintain the moisture content around 15 percent. With the exception of the maintained percentage of moisture, this experiment was made under field conditions. The result was that we had a fixation of 36 p. p. m. and an increase of 15.79 p. p. m. in the nitric nitrogen. This soil represents the sections used in these experiments and I take it is a fair example of the land in general, and fortunately it represents the land in question.

The relation of growing crops to this fixing flora is not known beyond the fact that the legumes are hosts to the nodule bacterium; otherwise the data that have come to my attention are not concordant.

The Nitrifying Efficiency of The Soils

The nitrifying power of these soils was shown by an increase of nitric nitrogen from 35 p. p. m. to 83.3 p. p. m. in 48 days. The sample kept in a show-bottle increased from 35 p. p. m. to 41 p. p. m. in the same time. These processes vary greatly from place to place within small areas. I have collected samples from this piece of land (not from the sections used in these experiments) that were very rich in nitrates which emphasizes the possibilities of the whole tract and the importance of the subject.

There seems to be no question but that the wheat had depressed, but not destroyed the nitrifying power of the soil. In August and September, after the wheat had been harvested, the development of the nitrates was slow but from September to December they increased 2.8 times, from 102 to 286 pounds in the top 4 feet of soil.

Some Important Effects of Alfalfa

The mechanical and biological conditions obtaining in soils that have been in alfalfa for 2 or more years are probably of much more importance than the small increase in total nitrogen that takes place. There is no increase in the nitric nitrogen in the soil; only the loose material on the surface may contain more of this form of nitrogen than usual, up to 30 p. p. m.

Cannot Apply Same Standards to Total and Nitric Nitrogen

We may be permitted to state explicitly what has been assumed in the preceding concerning small analytical differences. We have stated in one paragraph that the total nitrogen in the second 6 inches of soil in Section 100 that was planted to alfalfa exceeded that in the fallow portion of the same section by 0.0059 percent and we have raised the question whether this amount of total nitrogen is sufficient to justify any judgments that might be based upon it. The amount is small—236 pounds in the acre-foot of soil—besides in this form it is not available to the plants. On the other hand, a like amount of nitric nitrogen would be a very important factor. I think that in average agricultural soils 8 p. p. m. of nitric nitrogen or one-seventh of the amount just given would be considered a very fair supply, if not about the maximum to be expected.

Both of these determinations, total and nitric nitrogen, can be made with such accuracy that we can make no dis-

crimination between them on this account. Further they are equally capricious in their distribution in the soil so that we cannot justify ourselves on either of these grounds for rejecting larger quantities as insignificant in the one case, whereas we consider much smaller ones as of capital importance in the other. But we are fully justified by the different parts they play in the nutrition of plants.

It can scarcely matter much whether we have 6256 or 6000 pounds of total nitrogen in an acre-foot of soil, assuming that it is all nitrifiable with equal readiness, but it matters very much whether we have 50 pounds or only 5 pounds of nitric nitrogen per acre-foot of soil. In the case of the alfalfa we have a small increase in the former, total nitrogen, in the surface portions of the soil, but a very noticeable decrease in the latter to the depth of at least 4 feet. The total nitrogen is of value, principally, perhaps even wholly, only in the measure that it is nitrified, i. e., converted into nitrates which we consider as the only form available to plants. We do not know anything about the deportment of the nitrogen added to the soil by the alfalfa rotation. It may be either very easily or difficultly nitrifiable, with the chances, I think, in favor of the latter, as it has survived the changes of 2 or 4 years.

Gain in Total Nitrogen Due to Alfalfa

The gains in total nitrogen here shown for alfalfa ground are not greater than differences found for samples of soil taken from the same plot of ground on the same date. Still, I believe the increases given have been due to the alfalfa for the 61 sets of samples taken from alfalfa ground, each sample being made up of eight cores, are consistently higher than a like number of samples taken in the same manner from fallow ground. While fault may be found with our data, because our land was not really comparable, I believe that the generally accepted statement that the planting of land to alfalfa is a means for increasing the amount of total nitrogen in it is correct, and that our data show this to be the case. The data further show that this increase is confined largely to the top 6 inches of soil. We have other data that show that it is very largely in the upper half of this. The amount thus added is smaller than the importance heretofore attached to it would lead us to expect, still it is larger than the amount which would be added by the usual loss of leaves, etc., which takes place in hay making. This loss is not far from one-fifth of the crop at the time it is cut, or 1 ton per acre per annum if the crop be a good one. In 2 years this loss will add about 80 pounds of nitrogen per acre. The loss of

leaves prior to cutting is not very great in normal seasons, but if it should amount to as much as the loss in hay making we would add only 160 pounds, whereas, we have in the plot in Section 100, 286 pounds to the credit of alfalfa.

Owing to the great exaggeration of the loss of leaves prior to cutting, it will probably be fair to estimate the nitrogen added as a top dressing as equal to one-half of the total increase found in the top 6 inches. This would give a reasonable explanation for one-half of the 286 pounds, but we do not know how the other one-half is really to be accounted for and we attribute it to the alfalfa for we do not find any increase when the land is planted to wheat. This explanation is convenient whether it is satisfactory or not.

The Importance of Nitrogen Added by Alfalfa

What the value of this nitrogen may be is an entirely different question and one that we shall not try to answer at this time. This much, however, we will venture to say, i. e., that it is probably worth no more than an equal amount in the form of good barnyard manure and the increase given in the preceding paragraphs for the 2-year period in alfalfa would require about 5.5 tons of manure containing 1.5 percent of nitrogen every 2 years, which would be a very light fertilization.

The value of this form of nitrogen compared with that of nitric nitrogen is well illustrated by some results obtained in our wheat experiments. Nitrogen was added as barnyard manure at the rate of rather more than 1200 pounds per acre and it increased the total dry matter produced, mostly in straw, by a little, but the addition of 40 pounds per acre per annum in the form of sodium nitrate was by far too much and did more harm than good in a series of experiments extending over a period of 5 years.

We conclude that there is a slight increase in the total nitrogen of the soil when it has been in alfalfa 2 or more years, but that this increase is not great enough to be of much value. The nitric nitrogen in the soil is kept at a small quantity but nothing has been adduced to show that the nitrifying efficiency of the soil has been affected, though the nitric nitrogen under alfalfa is very low. We have not yet ascertained the deportment of the soil in this respect after the plantation of alfalfa has been destroyed.

Benefits of Alfalfa Rotation Not Due to Added Nitrogen

We do not believe that the benefits accruing to a soil from a rotation of alfalfa are due to the increased amount of nitrogen

in it, but to other factors, such as changes in the biological and mechanical conditions of the soil and in the amounts of other plant foods made available, potassium in particular, as we shall subsequently show.

EFFECTS OF ROTATION ON SOIL COMPOSITION

We attempted to ascertain what changes were brought about in these soils by a rotation of clover and alfalfa crops in 2 years. As the basis of this study, Mr. Tobiska made mass analyses of the soils and subsoils of two sections, i e., the north and south halves of our plot. The area of the plot was about one-half acre. He also made analyses by extracting the soil samples with hydrochloric acid, 1.115 sp. gr., also with fifth-normal nitric acid. The results are given in Table 11.

SOLUBLE SILICATES IN THE SOIL

The amount of silica soluble in saturated sodic carbonate solution, either originally present as amorphous silica or rendered so by evaporation with hydrochloric acid, is very moderate and indicates a small amount of soluble silicates. The average soluble silica is about 6 percent for the two samples of soil and essentially the same for the subsoils. The uncertainty of the value of these silica determinations is emphasized by the fact that felspar ground to the same degree of fineness and treated in the same manner will yield more than 1 percent of its weight of pure silica. The 6 percent of silica obtained from the soils represents not only soluble silicates, but also amorphous silica and that set free from minerals usually considered insoluble in hydrochloric acid. Even quartz yields to the same treatment. In an experiment with 5 percent caustic potash, quartz yielded 0.6 percent in 14 hours. Formerly it was stated that quartz sand did not yield silicic acid on treatment with a solution of sodic carbonate, but this statement is not entirely correct; it has its limitations.

In the mass analyses the loss on ignition less the carbon dioxid found is not put down as organic matter because it includes the water not expelled at 100° C. These analyses, especially that of the fifth-normal nitric acid extract, indicates a soil well supplied with available phosphoric acid and potash. The total nitrogen found in these soils, i. e., samples representing the north and south halves of the plot used was 0.1162 and 0.1232 percent respectively. The potential and available supply of mineral constituents indicated by the mass analyses and the analyses of the fifth-normal nitric acid solutions is adequate

TABLE 11.—Analyses of Soils and Subsoils used in Experiments on Effects of Alfalfa and Clover in Rotations.
Samples taken at beginning of experiments Nos. 2884 and 2885. Analyst, Mr. Tobiska.

	Mass Analyses				HCl, sp. gr. 1.115				Fifth-normal Nitric Acid Solution			
	Soil Percent	Subsoil Percent	Soil Percent	Subsoil Percent	Soil Percent	Subsoil Percent	Soil Percent	Subsoil Percent	Soil Percent	Subsoil Percent	Soil Percent	Subsoil Percent
Moisture, 100° C.	1.550	1.758	1.766	1.885								
Ignition	3.589	0.796	3.453	1.286								
Carbon dioxid	0.808	4.797	1.160	4.978								
Insoluble					74.651	65.718	73.578	64.523	90.158	84.290	88.698	83.550
Silica	71.295	62.298	69.430	61.305	6.637	5.885	5.728	6.361				
Sulfuric acid	0.137	0.137	0.127	0.188	0.054	0.065	0.054	0.072	0.025	0.007	0.032	0.017
Chlorin	0.101	0.081	0.153	0.062	0.101	0.081	0.153	0.062	0.101	0.081	0.153	0.062
Phosphoric acid	0.153	0.175	0.159	0.159	0.153	0.118	0.143	0.105	0.102	0.070	0.102	0.070
Aluminic oxid	11.550	11.575	12.000	12.200	5.130	5.920	5.640	5.900	0.810	0.020	0.800	0.010
Ferric oxid	3.846	3.964	4.142	4.142	3.273	3.375	3.406	3.419	0.172	0.047	0.133	0.039
Manganic oxid (br)	0.200	0.220	0.200	0.225	0.180	0.210	0.190	0.210	0.070	0.020	0.050	0.010
Calcic acid	2.650	8.025	3.225	8.275	1.700	7.045	2.260	7.375	1.635	5.500	2.155	5.625
Magnesic oxid	1.149	1.493	1.240	1.538	0.878	1.151	0.907	1.196	0.266	0.123	0.296	0.139
Potassic oxid	2.371	2.332	2.535	2.343	0.619	0.606	0.597	0.626	0.155	0.054	0.190	0.053
Sodic oxid	1.415	1.166	1.320	1.267	0.161	0.206	0.124	0.278	0.140	0.108	0.135	0.116
Sum	100.814	98.816	100.910	99.753								
Oxygen=Chlorin	0.023	0.018	.035	.014								
Total	100.791	98.798	100.875	99.739								

for the production of good crops. The nitrogen supply as indicated by the total nitrogen found is sufficient, though it is not very much above the conventional lower level given for good agricultural soils. In the case of our soils it is a question whether this lower limit is correct or nearly so, but if it is, our plot comes fairly within it.

Nitrogen being considered of great importance in these questions, we have already given our data at length to show in what quantities, both as total and nitric nitrogen, it is involved in our immediate questions. In the study of this phase of our work we have made many determinations of it in both forms and the average of eight samplings taken 6 inches deep is 0.1313 percent total nitrogen and for a like number of samplings from 7 to 12 inches, it is 0.1117 percent, an average of 0.1215 percent for the first foot against 0.1192 percent as the average of two samplings previously given.

The total nitrogen is not a fixed quantity, but it is in this case the only source of nitric nitrogen into which it is convertible. The rapidity or ease with which this takes place in the soil is very important and is, as we, in the proper place shall endeavor to show, influenced by the rotation here presented.

The mineral constituents required for the perfect growth of the plants, the potash and phosphoric acid—no others need be mentioned—must needs be supplied by the soil; they must be in solution at the time the plants appropriate them, however, the solution may be effected. This process of bringing these foods into the proper form for the use of the plants is a continuous one and is facilitated by the plants themselves. This statement may be both self-evident and trite; it is none the less important.

ALUMINA AND IRON IN THE SOIL EASILY SOLUBLE

The alumina in the soils and also in the subsoil is about 12 percent, while the ferric oxid is about 4 percent. The felspar of which this soil is largely composed carries about 18 percent alumina in the soil and more than three-fourths of the ferric chloric acid of 1.115 sp. gr. dissolves about one-half of the total alumina in the soil and more than three-fourths of the ferric oxid. Even a 10 percent solution of the acid with a digestion of only from 3 to 8 minutes attacks the soil very strongly, taking about 50 percent of the total alumina into solution. Fifth-normal nitric acid dissolves about 6 percent of the total alumina. This alumina seems very easily soluble, but is not objectionable so far as production is concerned.

This land produces from 40 to 60, or more, bushels of wheat per acre without the application of any fertilizers. Changes are constantly taking place in the amounts of these constituents in the proper form for the sustenance of the plants. We shall lay considerable stress upon the water-soluble potassium; at present, however, we present an attempt to ascertain other relations between our crops and the reactions proceeding in the soil.

Two Parts of the Soil Recognized

Two important divisions of the soil are recognized in this connection, the ultimate or mineralogical particles and the rest of the mass whether it is organized into aggregates or is not so associated. The former are usually looked upon as unalterable in any time that we are called upon to consider, while the latter forms the reactive portion of the soil. Of what these aggregates consist we have no very definite notion; zeolitic is frequently applied to them, but it is very questionable whether we have, in our case, any facts to justify the application; still we have to have some designation that suggests some property of them as they are understood and this designation serves the purpose. Some zeolitic minerals possess the property of exchanging bases under the right conditions and this is the property had in view. These aggregates include loosely held constituents and, like the zeolites, can exchange them under the right conditions. It is with these that the soil solutions are generally believed to be in equilibrium. A less frequently presented view is that the solutions are in equilibrium with the mineral particles. While the aggregates may play a part, the mineral particles may suffice to satisfy the mineral requirements of the crop grown. There is nothing exclusive in either view; each view probably represents a part of the truth and in so far is right.

Calcic Carbonate in the Soil

In Bulletin 319 of this station we described this soil and particularly the subsoil as presenting a case in which every quartz and felspar particle is coated with a film of calcic carbonate. The coarser particles are easily seen to be coated and the fine sands may be washed as clean as possible with water and yet will effervesce when treated with dilute acids. Even the part separated as clay in the mechanical analysis of the soil that has not previously been treated with acids contains a large percentage of carbon dioxid. We found 16.9 percent in such clay. When

the coarse sands washed out of the soil are treated with dilute acids the calcic carbonate goes into solution and a considerable portion of clay is set free. The clay and the carbonate of lime are very intimately associated.

SILICIC ACID SET FREE BY DILUTE ACIDS NOT ABUNDANT

The amount of silicic acid set free and subsequently soluble in boiling sodic carbonate or taken into solution by the acid solution is wholly insignificant—0.14 percent was found, less than one might expect to be dissolved out of the quartz sand and felspar forming the mass of the soil. In only one instance did organic matter or humus appear in these incrustations and that was in the case of a piece of sandstone picked out of the surface soil. The humus in this soil is low; the highest result obtained for it is 1.48 percent, usually about 0.67 or less.

We refer to our soils and climate as semi-arid; this is undoubtedly correct for the climate, as we have an annual rainfall of 14.9 inches and under dry-farming our soils do not have water enough to leach them and sometimes not enough to grow the crops. In our case the question arises in regard to the changes that 50 years of irrigation, which brings the annual water supply to 35 inches or more, may have brought about and now maintains in progressive action. Changes are certainly being made in the soil; it is, however, still a young soil compared with that of states even immediately to the east of us.

The samples were taken and the analyses of this part of our work were practically all made by Mr. Tobiska.

The work presents some difficulties: for instance, if a soil containing 10 percent of calcic carbonate be treated with a solution of ammonium chlorid we have reactions not wholly accounted for when we consider it a simple solution of calcic carbonate by the ammonium chlorid plus the exchange reactions that may take place between the ammonium chlorid and the aggregates and the mineral particles forming the basis of the soil. The amount of calcic salt taken into solution on treating the soil with half-normal sodic chlorid solution was in excess of .25 percent of the soil and a still larger amount in the case of the subsoil. We are not far from the mark when we consider this a fiftieth-normal solution of calcic chlorid which is sufficiently strong to influence the results of the treatment to a measurable degree.

Mr. Tobiska studied the reactions of the soil toward water. saturated solution of carbon dioxid, toward dilute acetic and

hydrochloric acids, also its deportment with normal ammonium chlorid after having been so treated.

Our procedure was based upon the amount of calcic carbonate present which we believe is, in our case, the principal aggregate-forming factor. With this in view we first determined the carbonic acid present in each sample of soil and calculated it as calcic carbonate. Next we standardized the dilute hydrochloric or acetic acid and added it in slight excess over the amount necessary to neutralize the calcic carbonate. This excess amounted to 10 or 15 percent of the amount used. The acid was measured and made up to 500 cc. and added to 100 grams of soil. This was allowed to stand 2 hours. This was longer than necessary, but was not otherwise objectionable. The solution and wash waters were separated from the soil by centrifuging it. These were evaporated to dryness and in the case of an acetic acid extract ignited, the oxids weighed, dissolved and analyzed. The washed soil was treated with five times its weight of normal ammonium chlorid solution for 4 hours when it was centrifuged as before, the solution and wash waters evaporated to dryness, the ammonium chlorid expelled by careful ignition and the residue analyzed. The residual soil was dried and weighed and the ammonium retained, determined by distillation with sodic hydrate. The ammonium fixed by our soils indicates the presence of a complex whose exchangeable bases are equal to about 13 milligram equivalents.* Our results vary as a rule from 11 to 14 and sometimes higher, but the most of them are about 13 milligram equivalents. The bases correspond very closely to the ammonium fixed.

We obtain the same fixation of ammonium by treating the soil directly with the ammonium-chlorid solution which shows that this complex is an individual component of the soil and that it is not seriously disturbed by our manipulation as given. If, however, we treat the soil with too strong an acid, say twice normal in only a moderate excess, we destroy the equality between the remaining bases and the ammonium fixed.

We take the constancy in the amount of ammonium fixed and the equality between the bases exchanged and this ammonium as proof of the existence of this complex, whatever its intimate composition or structure may be. It is not the whole aggregate but it is a part of it; the other part is that portion easily soluble in dilute hydrochloric or acetic acids and is also soluble in ammonium chlorid. The treatment with dilute acid divides the aggregate into two parts, one very easily soluble, represented in our statement by the analysis of the acetate solu-

*It is simply the hydrogen equivalent of the element.

tion or extract, and the other a little less soluble represented by the ammonium chlorid solution. These two, together, represent the actual crop-producing soil, but this does not exclude the other portions of the soil, the mineral particles, from direct participation in changes produced by the crop.

These aggregates are produced and maintained by the factors, temperature, air, moisture, vegetation, and to an important extent, carbon dioxid, which bring about the changes in the soil. These aggregates are comparatively stable in the conditions under which they have been formed but they are sensitive to changes in these conditions; a great increase of water, a change in the salt solution or an increase in the carbon dioxid will affect them. Water, carbon dioxid and very weak acid solutions do not seriously attack the complex, but ammonium-chlorid solution brings about the replacement of calcium, magnesium, manganese, potassium and sodium by ammonium.

We have not considered alumina and iron, though the hydrates of these oxids are very probably present in the complex. This may account for the fact that the ammonium-chlorid extract usually contains more of these oxids than the acetate solution. The amount is always small, negligibly so.

The first three analyses in Table 15a show the action of water, carbonated water and acetic acid, on these aggregates in a very strongly gypsiferous soil found near Fort Collins but not from our experimental plots. Years ago, 15 or more, this gypsiferous soil was white and the surface portion of it carried 75 percent of gypsum. I have seen fair crops of corn and oats grow on this land. The other eight analyses represent the top 16 inches of our west alfalfa plot and its adjacent fallow plot taken in 4-inch sections. These analyses were made by extracting the samples with carbonated water for 2 hours and subsequently treating the washed samples with ammonium chlorid for 4 hours.

A comparison of these results again raises the question about the value of water extraction. There is no recognizable point at which we can satisfactorily stop the process. In these analyses the digestion was continued for 2 hours just as in the case of the other solvents and we fail to get any very wide differences between them. The important feature in the composition of the extract is the potash dissolved. The water dissolved 275 p. p. m. and the acetic acid 330, a difference of 55 p. p. m. We may assume without much likelihood of error that the am-

monium chlorid dissolves all of the available potash when the soil is digested with it. If the soil has been extracted with acetic acid first and then with the ammonium chlorid, the two solutions contain the total. In this case we have in the aqueous solution, 275 p. p. m. and in the ammonium chlorid solution, 143 p. p. m., total, 418 p. p. m.; the water in 2 hours dissolved 66 percent of the total available, while the acetic acid dissolved 75 percent of the total in the sample treated for the same time. The difference in the totals in the two samples was 28 p. p. m. The water extraction gives a better result than we expected to obtain by it.

We believe that carbon dioxid and water play an important part in our question. We know further, that carbonated water is a much more vigorous solvent than pure water and we would make a much more satisfactory approach to the reactions in the soil by using it in preference to other solvents. Therefore, we give in this connection eight analyses in which this was used as the solvent. The samples analyzed were from our experimental plots. The essential features are again the potash recovered and the ammonium fixed by the complex. The analyses of the 1-foot samples of these soils are given in our general tables and the facts concerning the potash are restated on page 77. The average potash in the fallow plots at the end of 2 years' observation was found to be 703 p. p. m.; these analyses give 696 p. p. m. The results for the alfalfa soil are somewhat low; this is not surprising for after these samples were taken we found that the water-soluble potash in this plot varies exceedingly; the middle and southern part is much lower than the northern.

It has been stated that we digested the samples much longer than was necessary. A series of experiments was made in which the time of digestion with dilute acid—hydrochloric was used in this case—and with ammonium chlorid, was each one-half, 1, and 2 hours. The differences were very small; the widest ones were in the nitrogen fixed which we give as illustrative; one-half hour digestion, 0.1967; 1 hour, 0.1699; and 2 hours, 0.1727 percent, calculated on the air-dried samples.

MECHANICAL ANALYSES

Numbers 2884 and 2885 are respectively samples of the soil and subsoil from the north half of our plot, while Nos. 2886 and 2887 are corresponding samples from the south half. They were all taken at the beginning of the experiment. The analyses were made by Mr. Vail and resulted as shown in Table 12.

TABLE 12.—Mechanical Analyses of Soil at Beginning of Experiment.

Size of Sand mm.	No. 2884 Percent	No. 2885 Percent	No. 2886 Percent	No. 2887 Percent
1.5-1.0	0.894	0.214	0.846	0.108
1.0-0.5	6.439	2.322	5.229	1.595
0.5-0.25	31.522	21.244	18.821	14.407
0.25-0.05	17.501	12.766	19.791	23.382
0.05-0.01	18.144	26.811	25.855	23.413
0.01-Clay	12.520	18.700	14.183	18.041
Clay	7.136	10.453	8.479	11.218
Ignition	6.597	7.504	7.627	7.582
	100.813	100.023	100.837	100.746

Ignition includes moisture, organic matter and carbon dioxid; the latter is rather abundant.

The carbon dioxid in the separates obtained from composites of 2884 and 2886, also of 2885, and 2887, the former representing the soils, the latter the subsoils, was determined and calculated back to the air-dried soil.

TABLE 13.—Distribution of Carbon Dioxid in the Separates.

	Soil Percent	Subsoil Percent
Fine sand	0.020	0.394
Silt	0.244	0.692
Dust	0.355	2.279
Clay	0.414	1.790

The carbon dioxid accounted for in this way corresponds to 2.35 percent calcic carbonate in the soil and nearly 12 percent in the subsoil. The soil proper may be taken as having a depth of 1 foot without great variations.

The calcic carbonate was removed from the separates by treating them with the amount of dilute acetic acid calculated to be required to dissolve it, and they were allowed to stand till the carbonate had gone into solution; they were then washed and treated with five parts of ammonium-chloride solution for 4 hours.

The acetic acid solutions were analyzed by strictly conventional methods. These results show even more strongly than the carbon dioxid the differences between these separates.

We state in the following table the amounts of lime, magnesia, potash and soda found, calculated on the air-dried soil. The acetic acid was added in slight excess but never more than 20 percent more than the calculated amount. It is evident from the amounts given that the calcic acetate solution was quite strong.

TABLE 14.—Partial Analyses of Acetate Solution of Separates in Percentages of Air-Dried Soil and Subsoils.

	SOILS *2884-2886				
	Coarse Sand	Fine Sand	Silt	Dust	Clay
Calcic oxid	0.2283	0.3298	0.5860	2.5482	5.1030
Magnesic oxid	0.0040	0.0069	0.0259	0.0545	0.1487
Potassic oxid	0.0056	0.0037	0.0072	0.0210	0.1112
Sodic oxid	0.0063	0.0026	0.0033	0.0039	0.0087

	SUBSOILS *2885-2887				
	Coarse Sand	Fine Sand	Silt	Dust	Clay
Calcic oxid	1.6237	1.3840	2.2160	15.2240	13.7330
Magnesic oxid	0.0221	0.0268	0.0076	0.1952	0.2527
Potassic oxid	0.0130	0.0056	0.0077	0.0247	0.0595
Sodic oxid	0.0197	0.0037	0.0042	0.7705	0.8965

*This means that composites were made of these two numbers.

The finer the part, the richer it was in soluble salts. The lime, for instance, in the soil increased from less than 0.3 percent to over 5 percent. The potash and soda seem to be relatively higher in the coarse sand but not nearly so high as in the clay portion. The lime in the clay portion of the subsoil, also in the dust, is very high; its abundance was very evident from the color of the samples.

The subsoil is richer in magnesia, also in potash, than the soil in all portions except the clay in which it falls to about one-half, while the soda is higher in all portions of the subsoil.

The separates that had been treated with acetic acid and well washed were digested with normal ammonium chlorid, the solution analyzed and the soil treated for determination of ammonium. The results obtained are given in Table 15.

TABLE 15.—Partial Analyses of the Normal Ammonium Chlorid Extracts of the Separates, Soils and Subsoils.

		SOIL 2884-2886			
	Coarse Sand	Fine Sand	Silt	Dust	Clay
Calcic oxid	0.0138	0.0182	0.0909	0.3255	0.9772
Magnesic oxid	0.0012	0.0030	0.0186	0.0210	0.0426
Potassic oxid	0.0042	0.0020	0.0099	0.0456	0.2486
Sodic oxid	0.0048	0.0018	0.0050	0.0076	0.0141
Nitrogen retained by soil	0.0110	0.0110	0.2212	0.4831	0.7163
Mg. Eq. bases	0.796	0.999	4.542	13.947	42.763
Mg. Equiv. Ammonium	0.785	0.785	15.791	34.486	51.132

		SUBSOIL 2885-2887			
	Coarse Sand	Fine Sand	Silt	Dust	Clay
Calcic oxid	0.0558	0.0616	0.1592	0.5484	0.9580
Magnesic oxid	0.0026	0.0132	0.0388	0.0450	0.0320
Potassic oxid	0.0107	0.0040	0.0061	0.0157	0.0433
Sodic oxid	0.0204	0.0036	0.0064	0.0124	0.0284
Nitrogen retained by soil	0.0162	0.0245	0.0771	0.2640	0.6277
Mg. Eq. bases	0.796	0.999	4.542	13.947	42.763
Mg. Equiv. Ammonium	0.785	0.785	15.791	34.486	51.132

The nitrogen retained as ammonium by these respective separates increases rapidly with the fineness of the separates of both the soil and subsoil. These separates had been washed successively with water and dilute acid to remove the easily soluble portions including the carbonates of lime and magnesia (see the preceding tables). We know but little about the silicic acid, small amounts of which only went into solution with either acetic or hydrochloric acid; the latter dissolved about 0.1 percent of the air-dried soil or subsoil. The amount dissolved seemed independent of the amount of lime present. The amount dissolved by acetic acid was approximately one-third as much or 0.03 percent. If this factor has any significance it would be probably in showing that the amounts of easily decomposed silicates cannot be very large. Still it may be significant for the 0.1 percent soluble in hydrochloric acid might correspond to about 4 tons of these silicates per acre-foot or 1 ton in each million pounds of the air-dried soil. If it were present as a zeolite it would indicate a greater weight. We do not know enough about the part it plays in nourishing the plants to attempt an interpretation of its significance. Wheat, corn and some other plants

use a good deal of silica in their stems and leaves and this silica is soluble in water. In the changes going on in the soil, amorphous silica may be separated which may be a factor in the soil reactions, both in the field and laboratory. The few data that I have at my command can scarcely be made to support the notion that there is any accumulation of such silica in the finer separates, as in the dust and clay, for these are not especially rich in silica.

The milligram equivalents of the bases that go into solution in the ammonium chlorid solution and the ammonium fixed by the residues are not equal nor do they appear to follow any rule but they do show a marked increase with the increasing fineness of the residue.

Two Phases of the Reactions

There are two phases of this question. One relates to the complete removal of substances that furnish with the ammonium chlorid two solutions. The other relates to the changes in the residues. The solutions formed may be strong enough to have a decided effect upon the results especially upon longer standing. This applies to treatment with water, also, but to a less extent.

The water-soluble in this soil is around 0.4 percent including the organic matter and water in combination. The aggregate of this in a million pounds of soil is 2 tons, or about 8 tons in the surface foot of our soil. While we cannot specify or even indicate what reactions actually take place, it is probable that it is an important and active factor. Very light applications of fertilizers are credited with the production of big results. It would not be surprising that these very much larger quantities, though less active, should be important factors in plant production. They are undoubtedly active participants in the reactions going on in the soil which may be their more important function. This is a very general statement, but I have seen no more explicit one.

Water Extracts May Be Different From Soil Solutions

The solutions that we obtain by exhausting a soil with water may not actually represent those in the soil from which the plants obtain their mineral constituents, still they must be of the same general sort. We assume that the plants contribute to the formation of these solutions by acid excretions. They have been supposed to be equivalent to a 1 percent citric acid solution or possibly to fifth-normal nitric acid, hence their frequent use in such work. We believe that carbonic acid is the prevalent solvent in the soil. I have, however, found but one analysis of a soil in which carbonic acid was used as the solvent.

METHOD OF EXTRACTION ADOPTED

The Bureau of Soils of the United States Department of Agriculture used a method of studying the productivity of soils based upon a very brief treatment of the soil sample with especially prepared water to lessen the errors in the results that might be obtained. Their results showed that solutions obtained by their method with poor or non-productive soils were very similar to such as were obtained from productive soils in the amounts of mineral constituents present. These facts led to the assertion that some other cause than the supply of mineral constituents was accountable for the difference between productive and non-productive soils, especially when they were of the same character. The soils were in a sanitary or unsanitary condition for the crops grown.

It is our object at present simply to emphasize the fact that the water-soluble portion of the soil forms the nutritive solution for the plant and while we may not be able to make an extract that actually represents that solution at any given time, this is the nearest approach to it that we can make. The Bureau of Soils reduced the time of treatment to 30 minutes in order, I suppose, to obtain as nearly as possible the conditions in the soil at the time, almost at the instant of its examination. If this treatment be repeated another result will be obtained, but it will not represent the same conditions that the preceding represented. In the cases in which we carry the treatment with water to the point where no more sulfuric acid or chlorin goes into solution we have the composite sample representing a number of successive conditions which may be possible in the course of several seasons, but are not probable in any one season in our country of light rainfall, not even when we irrigate the land. Our water-soluble indicates only the total supply of mineral constituents available at the time we make the extraction and with the assumption that we have complete extraction when the sulfuric acid or chlorin disappears from the solution. This assumption serves as a criterion by which to work, but it is not true. The action of water is more than that of a simple solvent of ready-formed salts. This is why we shall give many data based upon a 30-minute treatment of the soil sample with water. The concentration of this solution is not negligible.

In the soils with which we have to deal, a solution made by treating one part of the sample with four parts water will contain more than one gram of soluble salts per liter; in the case of some soils, very much more. The salts in solution in the case of the soil treated of in this bulletin are predominantly those of

TABLE 15a—Efficiency of Water, Carbonated Water, and Acetic Acid as Solvents.

	PERCENTAGE COMPOSITION										
	Gypsiferous Soil			West Alfalfa Carbonated Water				Adjacent Fallow Carbonated Water			
	Water	CO_2 Water	Acetic Acid	1st-4 in.	2nd-4 in.	3rd-4 in.	4th-4 in.	1st-4 in.	2nd-4 in.	3rd-4 in.	4th-4 in.
Ignited extract	2.2846	2.5507	4.0625	0.4554	0.4922	0.4554	0.4556	0.3560	0.3053	0.4415	0.4427
CO_2 in soil	1.5440	1.5440	1.5440	1.5580	1.7740	1.2060	2.5315	0.4000	0.4600	1.4780	5.0700
Silica	0.0030	0.0127	0.0322	0.0252	0.0215	0.0230	0.0204	0.0268	0.0235	0.0193	0.0095
Sulfuric acid	1.3250	1.2610	0.8410								
Iron and alumnia	0.0060	0.0080	0.0295	0.0094	0.0074	0.0100	0.0036	0.0110	0.0110	0.0086	0.0048
Manganic oxid (br)	0.0015	0.0025	0.0060	0.0014	0.0004	0.0006	0.0004	0.0014	0.0010	0.0010	0.0008
Calcic oxid	0.7150	0.8805	1.8770	0.2074	0.2120	0.1960	0.2041	0.1454	0.1276	0.1936	0.2084
Magnesic oxid	0.1649	0.2105	0.3070	0.0166	0.0176	0.0186	0.0192	0.0134	0.0124	0.0184	0.0212
Potassic oxid	0.0275	0.0327	0.0330	0.0221	0.0212	0.0252	0.0276	0.0252	0.0236	0.0266	0.0251
Sodic oxid	0.0790	0.0757	0.0685	0.0044	0.0063	0.0058	0.0054	0.0053	0.0055	0.0059	0.0079
NH_4Cl extract	1.1560	1.0850	1.0320	0.9554	0.9176	1.0064	1.0046	0.9304	0.9450	1.0064	1.0176
SO_3 before ignition	2.1320	2.1220	2.1810								
SO_3 after ignition	2.1300	2.0960	2.1661								
Silicic acid	0.0106	0.0092	0.0206	0.0134	0.0098	0.0114	0.0088	0.0090	0.0134	0.0104	0.0064
Iron and alumina	0.0075	0.0055	0.0090	0.0080	0.0090	0.0065	0.0070	0.0045	0.0080	0.0075	0.0060
Manganic oxid (br)	0.0010	0.0010	0.0010	0.0015	0.0015	0.0030	0.0015	0.0020	0.0030	0.0015	0.0015
Calcic oxid	1.7485	1.7285	1.6685	0.4230	0.4275	0.4560	0.4325	0.3855	0.3905	0.4215	0.4515
Magnesic oxid	0.0455	0.0320	0.0315	0.0217	0.0148	0.0244	0.0188	0.0240	0.0255	0.0239	0.0278
Potassic oxid	0.0143	0.0115	0.0110	0.0430	0.0391	0.0466	0.0449	0.0465	0.0492	0.0452	0.0370
Sodic oxid	0.0159	0.0104	0.0141	0.0067	0.0067	0.0072	0.0056	0.0061	0.0072	0.0106	0.0067
Nitrogen fixed	0.0665	0.0817	0.1115	0.1700	0.2031	0.2255	0.1999	0.2207	0.2147	0.2063	0.1909
Mg. eq. of Ammonium	4.75	5.83	7.96	12.14	14.50	16.10	13.46	15.75	15.33	14.71	13.63

potash and lime. The soda, also the silicic acid, is low. The outstanding feature is the large proportion of potash that goes into solution; it forms from 15 to 25 percent of the total salts dissolved. This indicates an apparently large supply of potash, about 0.08 percent, or 800 p. p. m. We shall see later that this seemingly excessive supply, indicated by so drastic an exhaustion of the soil, is not so improbable as it at first sight appears.

CONCENTRATION OF SOIL SOLUTIONS

One cannot refuse place to the question how dilute or concentrated a solution of nutrients in the soil constitutes a merely sustaining, a good or an optimum condition for the plant's growth. I have seen the statement that a concentration of one part per million of phosphoric acid will suffice for the development of plants. The water extract of this soil gives approximately 16 p. p. m., finely ground felspar gave us 35 p. p. m. in 7 days, and finely ground apatite, 450 p. p. m. in the same time. I suppose that the one part per million was maintained constant and that the statement was intended to show the collecting power of the roots. Our extracts of soil, felspar and apatite show that so high a dilution as one part per million is probably never reached in soil composed largely of felspar carrying 0.156 percent phosphoric acid.

These somewhat digressive statements have been made to show what importance we attach to extraction by water and to the extract itself. Besides, we shall have very little more to say about the phosphoric acid in our soils. While we do not believe that there is much, if any, object in trying to make a long continued extraction of the soil with water, it is not improbable that a short extraction remains as good a criterion of its crop value as we have. In heavy alkali soils its value depends upon the obtaining conditions. We have many soils of which it would be objectless to make such an extraction for this purpose. The results would be too involved and misleading. Our question is what relation such extracts may have to the changes going on in the soil over a period of time, three seasons in our case. We hope that by adopting a procedure and adhering to it strictly throughout we shall be able to obtain a definite view of the effects of our rotation.

METHOD OF EXTRACTION IMPORTANT

The question of method is important. There are water-soluble salts enough present to constitute a factor, but there is also calcic carbonate enough present to modify the reactions with

any more active reagent. Sodic chlorid is an energetic solvent but I do not think that it exaggerates the importance of calcic carbonate in these reactions. Fifty grams each of felspar, soil and subsoil, were digested for 4 days with a half-normal solution of this salt; the felspar yielded 22 p. p. m. of lime; the soil yielded 2984 and the subsoil 3688 p. p. m. Calcic chloride in half-normal solution acts moderately upon unaltered felspar, but is a weaker agent than sodic chlorid. It may be added that in these experiments the felspar yielded 294 p. p. m. of potash to the sodic chlorid solution, while the soil and subsoil yielded 648 and 432 p. p. m. respectively. The lime that went into solution did not apparently affect the amount of potash that was dissolved, but it has already been stated that calcic chlorid acts moderately upon felspar, removing principally potash. The potash in the soil is evidently more readily soluble than in the felspar, which contains about four times as much and yields only a few parts per million more than the soil.

The Carbonate of Lime Is Associated With the Clay

We were perplexed about the relations of this carbonate of lime to the soil solutions and complexes of which it may actually form a part, at least the incrustations covering the soil grains are made up of calcic carbonate and clayey particles and the mechanically separated clay is very rich in calcic carbonate; there may be nearly 40 percent of carbonate in the clay. The best way of meeting this question seemed to be to determine the carbonic acid, calculate the calcic carbonate corresponding to this and add slightly more dilute acetic acid than would be necessary to bring this carbonate into solution. We tried hydrochloric acid but we thought that it did not give as good results as the acetic acid but a standardized solution added in only slight excess can be used. The effort gave interesting results as will appear later.

Calcic Carbonate and Soil Aggregates

Observations recorded in Bulletin No. 319 indicate rather strongly that this calcic carbonate may form a large part of the aggregates and coats the soil grains with a similar material which probably acts in the same manner as the aggregates themselves toward soil solutions.

The solution obtained by treating the fine earth from the subsoil with dilute hydrochloric acid (1:2) in the cold for from 3 to 8 minutes corresponded to about 72 percent of calcic carbonate with some silica (very little), rather an abundance of

alumina and iron, potash and phosphoric acid; in short, it was a solution containing the nutritive compounds usually looked for in a soil. It was not the object of the experiment to determine the proportions of these elements taken into solution, still it removed almost the whole of the easily soluble potash and one-third of the total phosphoric acid. A very brief treatment with dilute acid must have changed the character of this soil wholly and left but little as representative of the soil aggregates. These aggregates have a physical significance as well as a chemical one, but we concern ourselves with the chemical one only. The analytical results indicate that though we did not add the dilute acid in excessive quantity and allowed it to act for only a few minutes (3 to 8), the actual effect was to exhaust the soil to a greater extent than we at the time desired. Some partial analyses of such solutions together with analyses of solutions obtained by treating the washed residues with a normal ammonium chloride solution will be given subsequently.

Acetic acid, diluted with two volumes of water, added in an amount slightly in excess of that calculated to be necessary to dissolve the calcic carbonate and allowed to stand 2 hours, gave more satisfactory results. The solution was separated, and the residue washed with water till deflocculation was persistent; this required five washings. The soil was then transferred to a proper vessel with not more than 450 cc. of water, 27 grams of ammonium chlorid added and the volume made up to correspond to 500 cc. of solution. The whole was stirred several times during the first 30 minutes and then allowed to stand 4 hours in all.

The ammonium-chlorid solution from the soil, with washings, was evaporated and subsequently analyzed. The soil was still further washed to avoid possible error due to residual ammonium chlorid, dried, weighed, and the ammonium remaining in the soil determined by distillation with sodic hydrate. This procedure gave very different results from those obtained by the use of dilute hydrochloric acid, 1:2, in excess, and they appear to be much more significant.

THE WATER EXTRACT

The aqueous extracts of these samples contain considerable quantities of salts especially potash with silica and lime following in order, though calcic carbonate, even in the finely divided form in which it here occurs, is very slightly soluble in water. There is very little calcic sulfate in this soil though it is very abundant in some soils even in this section of the state.

CARBONIC ACID AND WATER

Carbonic acid and water acts strongly on these samples. In a test made on this soil and subsoil, the lime, CaO, that went into solution was equal to 1.011 and 1.534 percent of the respective samples. This was very much more than was taken into solution by the half-normal sodic chlorid solution. The amount of potash taken into solution from the soil and subsoil respectively was 590 and 330 p. p. m. The question as to what sort of compounds or aggregates this potash is derived from is unanswerable for we have seen that potash is the principal constituent that goes into solution when unaltered felspar is treated in this manner. There is nothing but the large amount, 590 and 330 p. p. m., to indicate that it comes from other sources. We believe that it does, for the most part at least; for potash in some manner or other is held though loosely by soils. It is held so loosely that it makes from 15 to 25 percent of the total soluble in water.

There are other difficulties in making an aqueous extract of a soil for analysis than those previously mentioned. It is comparatively easy to extract 10 grams and get results closely approximating the truth in the case, but it is a very different matter to extract a thousand grams so thoroughly that one gets equally reliable results. With 10 grams we will use 750 or 1000 cc. of water, but we would scarcely be equipped with either facilities or patience to handle 1000 grams with equal care and thoroughness. The percentage of soluble matter obtained falls rapidly with the increase in the amount taken. With 10 grams we got, after ignition, 0.301 percent; with 250 grams, 0.124 percent; and with 1200 grams we got only 0.0856 percent. In the last case we used, in round numbers, 14 liters of water.

The object in using so large a sample was to obtain a sufficient quantity of fixed residue for a satisfactory analysis. The loss on ignition amounted to 36.8 and 42.0 percent of the dried water-soluble, or 0.0042 and 0.0034 percent of the air-dried soil. The filtrates in this case were passed through Pasteur-Chamberland filters. The first portions that pass into solution are not identical in composition with the later portions. The best that we can say for an extract made in this manner is that it is a fair representative of the easily soluble salts whether they are entirely free in the soil or loosely held in the complexes. The presence of potash to the extent that we find it would suggest the latter. If so, our washing probably leaves the samples in only a little less unsatisfactory condition for treatment with ammonium-chlorid solution than they were originally.

TABLE 16.—Analyses of Aqueous Extracts of Soils at the Beginning of Our Experiments.

	No. 2884 Percent of Air-Dried Soil	No. 2886 Percent of Air-Dried Soil
Silicic acid	0.01700	0.02920
Iron and alumina	0.00353	0.00375*
Manganic oxid (br)	0.00029	0.00028
Calcic oxid	0.04054	0.04387
Magnesic oxid	0.00520	0.00546
Potassic oxid	0.01859	0.03243
Sodic oxid	0.00108	0.00154
Phosphoric acid	0.00115	0.00144
	0.08738	0.11797

*The alumina found on purifying the silicic acid was decidedly more than I expected. The manipulation of the material would lead one to expect this alumina to contain titanic acid if it were present and soluble in water. The alumina was dissolved by fusion with potassic bisulfate and the melt dissolved in a mixture of sulfuric acid and hydrogen peroxid. The solution could easily have been compared with a standardized titanic acid solution. The percentage calculated on the air-dried soil would have been small.

In former work I have been reluctant to assert that titanic acid found in the crude ashes of various plants really belonged to the plant and not to the contaminating earth, which is very difficult to avoid. In this case it evidently went into solution with the silicic acid and was rendered difficultly soluble by the ignition and remained with the silicic acid after evaporation.

We grew maize on a part of this plot in 1927. We had previously examined maize leaves for titanic acid and found it in comparatively large quantities. We gathered some of the stalks grown on this ground, removed the leaves and sheaths, cleaned the stalks, burned them, and examined the ash for titanic acid. It was present, but the quantity was not determined. As the titanic acid went into solution in water it is not surprising that it should be present in the ash of these plants.

The direct weighings of the ignited residues gave 0.0856 and 0.1125 percent, with which the analytical results are nearly identical.

The difficulty in obtaining a representative aqueous extract of soils is shown by the following results obtained with these samples, Nos. 2884 and 2886, in order to prepare enough of the soluble salts for an analysis according to our usual procedure in the case of soils rich in alkalis. The time consumed in making the extract was quite long. Fermentation of some sort set in and we obtained a most ill-smelling mass of salts. This land had not received any application of manure for a number of years. The yield was disappointingly small and it was impossible to prepare a workable solution without first destroying the organic matter by ignition. The analyses in Table 17 have been calculated on the residue dried at 100° C. for 20 hours. These are given to show that these residues are not representative.

TABLE 17.—Analyses of Water-Soluble Portions of Soils, Nos. 2884 and 2886, Different Extraction.

	No. 2884 Percent	No. 2886 Percent
Silicic caid	7.290	7.287
Sulfuric acid	4.381	3.484
Chlorin	1.058	Not Determined
Phosphoric acid (P_2O_5)	0.431	0.402
Ferric and alumnic oxids	0.034	0.030
Manganic oxid (br)	0.040	0.032
Calcic oxid	10.053	6.193
Magnesic oxid	0.079	0.042
Potassic oxid	15.009	24.803
Sodic oxid	1.393	1.039
Ignition	(60.232)	(55.460)

Moderate ignition, not strong enough to burn out the carbon completely, gave 58.0 percent loss against 60, in brackets, and 53 against 55. The percentage of this residue was much below that usually obtained from this soil. This is the reason for its repetition as given in the text.

The extracted soil was dried, rubbed in a porcelain mortar avoiding grinding as much as possible and passed through a 20-mesh sieve. This was done to bring it back approximately to its original mechanical condition. This grinding was unavoidable because the washed and air-dried soil had become very hard. We assumed that the small particles, now plainly discernible, to be cemented by clay-like material, would thoroughly disintegrate on being wet with the ammonium-chlorid solution.

AMMONIUM FIXED VARIES WITH FINENESS OF PORTION

Reference to the results obtained with separates from the mechanical analyses show that the replacements varied with the fineness of the separates even though we supposed that the clay had been thoroughly removed from all of them except the clay portion itself. The clays contained better than 38 percent of calcic carbonate and fixed respectively 51 and 45 milligram equivalents of ammonium, while the dust fixed 34 and 19 milligram equivalents respectively. The clay portion is very much finer than the dust which is presumably free from clay. The calcic carbonate in the clay portion went into solution in the ammonium chlorid to some extent; this is true too of the dust and the milligram equivalents of this lime appears in the sum of the equivalents of the bases. In spite of the treatment of these separates with dilute acetic acid, in slight excess, to dissolve the calcic carbonate the milligram equivalents of the bases in the subsoil are in excess of those of the ammonium, which is as we would expect it to be, but in the case of the soil the ammonium eqiuvalents are rather strongly in excess. In both samples, however, the equivalents increase with the fineness of the separates and do not seem to be dependent upon the clay.

In ordinary laboratory practice we avail ourselves of the effects of fine pulverization to facilitate reactions between solids and liquid reagents and the reactions are affected by the degree of fineness. Some such thing seems to be the case in these samples though we are accustomed to consider clay as influencing these facts by virtue of properties other than its fine division. There is no question about the retention of potassium compounds by soils and this property has been associated with the clayey components, also the zeolitic constituents.

In an analysis of the clay separated from these samples which will be given a little later, it will appear that in this case the clay is no richer in potash than the mass of the soil. There does not appear to be any accumulation of potash in this component. It may be more reactive, but we have no means of judging this. The presence of a large percentage of felspar in this soil carrying 4 or 4.5 percent of potash* is a factor beyond any question.

THE EFFECTS OF GRINDING THESE SOILS

The composition of the residues from the aqueous extracts of these soil points to them as products of mineral decomposition as well as to the aggregates in the soil. If this is true, they do not represent only ready formed salts in the soil but also some that are produced by the operation. In connection with these questions we believed that we would get some data by treating with ammonium chlorid some washed soil ground to pass a 20-mesh sieve and also portions of the same samples ground to pass a 200-mesh sieve. In this case there are no differences in the chemical or mineralogical constituents; the only difference is in the size of the particles. The soil as it passed the 20-mesh sieve contained a considerable portion much finer than was necessary to pass this sieve but it was not permissible to remove these portions as this would radically change the samples. A sieve analysis of this material gave the results shown in Table 18.

TABLE 18.—Sieve Analysis of the Material that Passed the 20-Mesh Sieve.

	No. 2884 Percent	No. 2886 Percent
Greater than 40-mesh	8.20	7.14
Greater than 60-mesh	5.06	4.40
Greater than 100-mesh	12.46	9.64
Greater than 200-mesh	17.90	14.64
Less than 200 mesh	58.38	64.18
	100.00	100.00

*The felspar particles, i. e., pieces big enough to be picked out of the soil sands, appear very much like fresh felspar, but contain only 4.5 percent potash against 10.5 in the fresh mineral; but as this is easily acted on by water and carbonic acid, setting potash free, one would expect potash to be accumulated in the clay to a greater extent than we find to be the case.

These analyses represent the stock soil that passed the 20-mesh sieve. A portion of each of these was taken and ground in an agate mortar till all of it passed a 200-mesh sieve. In round numbers, 40 percent of these samples had to be reduced to pass this sieve. How much the 60 percent may have been reduced, I do not know, nor do I know what other changes than the reduction in the size of the particles may have been produced in them. One hundred grams of each of the four samples were treated as usual with 500 cc. of normal ammonium chlorid solution. These samples were not treated in any manner after extraction with water and drying before pulverization. The analytical data obtained on examining these samples are given in Table 19.

TABLE 19.—Partial Analyses of Ammonium-Chlorid Solutions Obtained with Samples that Passed a 20-mesh Sieve.*

	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0044	0.154	0.0048	0.126
Calcic oxid	0.3680	13.123	0.4208	15.005
Magnesic oxid	0.0294	1.458	0.0337	1.672
Potassic oxid	0.0502	1.066	0.0756	1.605
Sodic oxid	0.0512	1.652	0.0172	0.555
		17.414		18.963
Ammonium		11.779		13.692
Excess of bases		5.635		5.271

TABLE 20.—The Same as Preceding, but Stock Passed Through a 200-mesh Sieve.

	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0064	0.168	0.0064	0.168
Calcic oxid	0.3736	13.323	0.4164	14.804
Magnesic oxid	0.0331	1.635	0.0370	1.835
Potassic oxid	0.0642	1.363	0.0852	1.809
Sodic oxid	0.0640	2.064	0.0208	0.671
		18.553		19.287
Ammonium		18.889		18.089
Excess of bases		0.336		1.196

The amount of soda, 0.0512 percent, in the first analysis of No. 2884, is unusually high for this series. It is evident from the results given that we have changed the replacements by simply pulverizing the samples and increased the ammonium fixed by the soil. In No. 2884 the total change is about 7 milligram equivalents or better than 60 percent of the total in the original; in No. 2886 the change is about five equivalents or 32 percent in the

*The percentages are calculated on air-dried sample.

same direction as in the preceding sample. The only difference in the two pairs is in the fineness or pulverization of the samples. In the finer material the ammonium fixed is very nearly equal to the bases that went into solution, which was not the case in the coarser material.

In order to get a further idea of the relation of the fineness of the particles to the fixation of the ammonium and how much it depends upon the nature of these particles, 300 grams of the samples were shaken violently and repeatedly with water and rubbed with a rubber pestle in a porcelain mortar and the turbid mass poured onto a 200-mesh sieve to remove all that would pass it with gentle washing. The portion remaining on the sieve, about 40 percent of the soil, was dried in the air and pulverized to pass the 200-mesh sieve. This powder was treated with ammonium chlorid in the same manner as the previous samples and gave us the following results.

TABLE 21.—Results Obtained with the Coarser Portions of Samples Nos. 2884 and 2886, on Treatment with Ammonium Chlorid After They Had Been Ground to Pass a 200-mesh Sieve.

	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Iron and alumina	0.0108	....	0.0112	....
Manganic oxid (br)	0.0040	0.105	0.0036	0.096
Calcic oxid	0.2324	8.216	0.2026	7.233
Magnesic oxid	0.0191	0.947	0.0133	0.660
Potassic oxid	0.0338	0.718	0.0298	0.633
Sodic oxid	0.0200	0.645	0.0192	0.620
		10.631		9.242
Ammonium		4.372		2.484

The action in this case is upon the mineral particles and while ammonium is taken up the replacement is only partial but shows that replacement takes place in the constituent minerals when finely enough ground.

The clay washed out of No. 2884 and 2886, a composite sample, was examined in the same manner as the soils and the results are given in Tables 14 and 15, but in this place we give a complete mineralogical analysis of it as it was prepared by washing with acetic acid to remove the calcic carbonate, but it had not been treated in any other manner.

In connection with the analysis of the acetic-acid solution, attention was called to the amount of potash that went into solution. We observed also that water dissolves out liberal quantities of this constituent, which may indicate that the aggregates are attacked. We have already expressed the opinion that the calcic carbonate may form a part of these aggregates and have

stated that clay is liberated when the incrustations of carbonate are dissolved off of the washed sands. The extent to which this destruction of the aggregates may be effected in this manner is a serious uncertainty but the acetic-acid solution—we mean the calcic acetate formed as well as the excessive but very dilute acetic acid, itself—may react quite energetically with them. We are inclined to attach a good deal of significance to the potash that appears in these solutions.

The double number 2884-2886 indicates that this clay was washed out of a composite sample formed from these two.

TABLE 22.—Analysis of Clay Washed Out of Nos. 2884-2886; Calcic Carbonate Removed by Dilute Acetic Acid.

	Percent
Silicic acid	49.80
Alumina	11.05
Iron oxid	17.95
Lime	0.55
Magnesia	2.45
Potash	2.70
Ignition	16.26
	100.76

The ferric oxid is high and the alumina is low; otherwise it presents no exceptional features as a rather pure clay. Two percent of alkalis is rather high for ordinary clay but it is low rather than high under the conditions. We tacitly assume that the alkalis are not soluble in water, especially the potash, because of the ability of the soil to absorb or fix it. We do not know whether the potash that appears in the acetate solution belongs there or not, but we believe it does. The silicic acid in the analysis is lower than one would expect it to be in a product obtained in the manner that this was, as a mechanical portion of a soil in which we have reason to believe amorphous silica may occur. This completes our presentation of the soil factors at the beginning of the experiments.

WHY WE DID NOT USE HYDROCHLORIC ACID

We have used water to remove soluble salts such as are not supposed to be in any kind of combination in the soil. This soil shows effervesces under proper conditions. The calcic carbonate is a disturbing factor but it is a component of our soil. The question of how we should treat it had to be solved; the data relative to the separates show that it is a very real question. We tried to dissolve out the carbonate after having determined the carbon dioxid and calculated the calcic carbonate corresponding to it, by treating the sample with a slight excess

of dilute hydrochloric acid. This gave unsatisfactory results. The action was too vigorous; at least, the treatment with ammonium chlorid failed to give even an approximate equality of the equivalents of the bases that went into solution and the ammonium fixed. The ammonium fixed was in excess of the bases removed by the ammonium chlorid and the equivalents of both were much lower than when we used acetic acid. The samples 2884 and 2886 were not treated with hydrochloric acid, but fifteen other samples were treated in this manner and agree in showing the results just stated. We used an excess of dilute 1:2 hydrochloric acid and attacked the complex.

We will give partial analyses of the ammonium-chlorid solution of two soils, Nos. 2920 and 2924, with those of the corresponding subsoils Nos. 2921 and 2925 after extraction with acetic acid together with similar analyses of acid solutions after the hydrochloric acid extraction.

These analyses will serve to show how vigorously the dilute hydrochloric acid attacks these soils, a fact that we have emphasized previously in Bulletin 319 for a subsoil from this land taken perhaps 125 feet from the south end of this plot.

TABLE 23.—Analyses of the Hydrochloric Acid Solutions, Percentage on Air-Dried Material.

	No. 2920 Soil Percent	No. 2921 Subsoil Percent	No. 2924 Soil Percent	No. 2925 Subsoil Percent
Carbonic acid	0.6580	4.9870	0.4910	5.0510
Silicic acid	0.1142	0.1117	0.0954	0.1076
Phosphoric acid	0.0804	0.0792	0.0734	0.0741
Iron and alumina	0.4350	0.4950	0.4720	0.5190
Manganic oxid (br)	0.0280	0.0240	0.0240	0.0190
Calcic oxid	1.1960	6.5840	0.9970	6.7480
Magnesic oxid	0.1031	0.2635	0.1035	0.2574
Potassic oxid	0.0757	0.0428	0.0581	0.0633
Sodic oxid	0.0069	0.0117	0.0281	0.0164

The acid used in making these extracts was diluted, one of acid to two of water, and the extreme time of treatment was 15 minutes. The solutions were separated from the soil by centrifuging which was more convenient and certain than filtering. The composition of the hydrochloric acid solution of this calcareous portion of the subsoil is also given in Bulletin 319, pp. 32-35, but for a slightly different purpose.

The object of giving these data here is to show the vigorous action of this acid on these soils and to exhibit the composition of the solutions in percentages of the soil taken.

The alumina and iron oxid is very high, the lime and mag-

nesia also, but we have elsewhere seen that every sand grain in this soil is coated with a clayey carbonate of lime. The clay in these coatings is not abundant but the carbonate of lime is very abundant in the mechanical portion designated clay. Perhaps the most suggestive feature in the composition of these hydrochloric-acid solutions is the amounts of phosphoric acid and potash that are very readily soluble. This was also pointed out in Bulletin 319, page 41.

The soil, after having been treated with this hydrochloric acid and washed with water, was treated with normal ammonium-chlorid solution in regulation manner, the solution analyzed and the ammonium finally determined in the soil. The results are given in percentages of the air-dried soils.

TABLE 24—Partial Analyses of the Ammonium-Chlorid Solutions of Soils After Treatment with Dilute Hydrochloric Acid.

	No. 2920 Soil		No. 2921 Subsoil	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0016	0.042	0.0012	0.031
Calcic oxid	0.0348	1.243	0.1440	5.145
Magnesic oxid	0.0113	0.561	0.0160	0.798
Potassic oxid	0.0195	0.414	0.0134	0.285
Sodic oxid	0.0047	0.152	0.0021	0.068
		2.412		6.327
Ammonium		7.895		9.487

	No. 2924 Soil		No. 2925 Subsoil	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid	0.0008	0.021	0.0008	0.021
Calcic oxid	0.0236	0.843	0.1428	5.102
Magnesic oxid	0.0106	0.526	0.0153	0.759
Potassic oxid	0.0208	0.442	0.0159	0.388
Sodic oxid	0.0094	0.304	0.0055	0.178
		2.116		6.448
Ammonium		8.323		9.309

The amount dissolved by the ammonium chlorid is small and the milligram equivalents are correspondingly low and the ratios are wrong. If a replacement had taken place the bases and the ammonium should be equal or nearly so. The other eleven samples done in this manner gave similar results. The method did not promise to give us enough useful information about the soils to justify its continuance.

We treated these samples, Nos. 2920, 2921, 2924 and 2925, being respectively soils and subsoils, with acetic acid, as well as with hydrochloric acid and present the results for comparison with those obtained by first treating them with hydrochloric acid, which have just been given.

TABLE 25.—Partial Analyses of the Acetic-Acid Solutions of Soils and Subsoils in Percentages of the Air-Dried Samples, Nos. 2920, 2921, 2924, and 2925.

	No. 2920 Soil Percent	No. 2921 Subsoil Percent	No. 2924 Soil Percent	No. 2925 Subsoil Percent
Manganic oxid (br)	0.0012	0.0080	0.0022	0.0090
Calcic oxid	0.7442	5.9790	0.5565	6.0760
Magnesic oxid	0.0318	0.0792	0.0308	0.0865
Potassic oxid	0.0303	0.0228	0.0284	0.0394
Sodic oxid	0.0042	0.0072	0.0045	0.0073

TABLE 26.—Partial Analyses of Ammonium-Chlorid Solutions of Preceding Samples After Treatment With Acetic Acid.

	No. 2920 Soil		No. 2921 Subsoil	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0048	0.126	0.0016	0.042
Calcic oxid	0.3028	10.820	0.3848	13.750
Magnesic oxid	0.0204	1.012	0.0250	1.240
Potassic oxid	0.0391	0.830	0.0180	0.382
Sodic oxid	0.0051	0.165	0.0032	0.013
		12.953		15.517
Ammonium		13.342		11.157

	No. 2924 Soil		No. 2925 Subsoil	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0028	0.073	0.0016	0.042
Calcic oxid	0.2988	10.677	0.3868	13.831
Magnesic oxid	0.0226	1.121	0.0269	1.334
Potassic oxid	0.0415	0.881	0.0258	0.548
Sodic oxid	0.0034	0.110	0.0032	0.101
		12.862		15.856
Ammonium		15.371		11.535

HYDROCHLORIC ACID DESTROYED RATIOS OF MILLIGRAM EQUIVALENTS

The hydrochloric acid took much larger quantities of bases into solution than the acetic acid; this influenced the amount of bases that went into solution in subsequent treatment with ammonium chlorid and altered the ratio between these and the ammonium fixed by the residual soils, both of which are very low. The bases were lowered more than the ammonium.

In the cases of the soils treated successively with acetic acid and ammonium chlorid, the milligram equivalents for bases and ammonium are in better agreement. The excess in the subsoil is due to excessive lime and the error is on the right side. This error will be frequently found in the subsoils which are rich in calcic carbonate. If we are correct we should expect rather

close agreement in the exchange values of the soils but a tendency to high values for the bases in the subsoils. In the analyses of Nos. 2884 and 2886 washed with water, the calcic carbonate was not removed and we have high equivalents for the bases which still holds for No. 2886 after pulverization to pass a 200-mesh sieve but in a far less degree.

Pulverization Altered Ratio of Milligram Equivalents

Pulverization in this case changed these relations materially, which shows that the calcic carbonate or clay that may be present are only contributing and not exclusive factors determining the fixation of ammonium. The milligram equivalents of the bases taken into solution are very nearly equal in the respective pairs but the ammonium fixed has been increased by the grinding. In this case the two samples, identical in every respect except in the degree of fineness, show very different degrees of ability to fix ammonium. We do not know how much we may have comminuted or otherwise changed that portion, 60 percent of the whole in round numbers, that already passed the 200-mesh sieve, but we know that we reduced 40 percent of the mass, one-half of which would not pass a 100-mesh sieve, to pass a 200-mesh sieve. How much of this was fine enough to pass a 225 or 250-mesh sieve we do not know, but our results show that this question is of some importance.

Conditions of Interpretation

We shall depend upon the following conditions as the basis of our interpretations: First, we shall uniformly use air-dried samples. This will reduce them to an almost constant and uniform percentage of moisture and they will probably change from their fresh or field condition by about the same amount and in the same direction on drying in this manner. We shall treat them with dilute acetic acid in amounts only slightly in excess of that required to dissolve the calcic carbonate present whose amount has previously been determined. This is done to remove the carbonate as completely as the conditions permit and also the lime solution formed to prevent their taking part in subsequent reactions. We shall use a fine earth that passes a 20-mesh sieve and assume that the relative amounts of the different-sized particles in the plots remain essentially the same throughout our experiment. We shall use normal ammonium chlorid solution, five parts solution to one of soil, and digest 4 hours. The essential datum for our purpose is the ammonium or its milligram equivalent that remains fixed in the soil. We shall give the bases removed by the ammonium-chlorid solution and shall add to

these the composition of the acetic-acid extract because much besides lime and magnesia goes into solution and we believe this extract to have great value. The reader is entitled to know this composition in order to judge of this himself.

The composition of this solution probably presents as faithfully a reflection of the changes that take place in the soil as any other single factor and is presented because of its own value as well as to complete the statement of data. This solution represents an important portion of the soil containing bases more readily soluble and available than those exchanged with the ammonium. We have effected a division of the nutrients, particularly the potash and probably of the phosphoric acid also, into more and less readily soluble portions which gives us a more intimate view of the soils' capabilities than we have otherwise obtained. The phosphoric acid has not been given in our regular statement of the acetic acid extract, but the phosphates in the soil are soluble in acetic acid, which is not surprising as it is present in the aqueous extract and yet we find it stated that it is not soluble. We found 0.0042 and 0.0027 percent of the air-dried soil in two of these extracts made to get rid of the excess of lime salts. The four places in the percentage statement are given because it can as readily be read in parts per million if wished.

Extraction with water is so difficult that it is practically prohibited when we attempt to operate with larger quantities of soil, but this acetic-acid extraction is feasible and does not extract the more firmly fixed bases replaceable by ammonium as easily as the hydrochloric acid does. The relations of the potash in this connection are important. We shall adopt another manner of investigating these later, because the quantities involved are too small to be determined expeditiously and satisfactorily by gravimetric methods, and if they were, the labor involved is entirely too great. It will be observed later that so far as our purposes are concerned the results obtained by the two methods are concordant.

We shall include manganese among the exchangeable bases because it is uniformly present in our soils and in their aqueous extracts, and is uniformly present in plant ashes. The milligram equivalent is small but it belongs in the reckoning and should appear.

How much, if any, of the bases that go into solution in water or acetic acid used as in this procedure belong in the complexes, each reader must judge for himself. I do not think that they belong there or at most to only a small extent.

STATUS OF SOIL CONDITIONS AT BEGINNING OF EXPERIMENT
CONDENSED STATEMENT

The cases of Nos. 2884 and 2886, two samples of the soil taken at the beginning of our experiment, are repeated here in their essential features that a better view of them may be had and a better judgment formed of the merits of the methods of investigation.

TABLE 27.—Sieve Analysis of the Samples as They Passed a 90-mesh Sieve.

	No. 2884 Percent	No. 2886 Percent
Remained on 40-mesh	8.20	7.14
Remained on 60-mesh	5.06	4.40
Remained on 100-mesh	12.46	9.64
Remained on 200-mesh	17.90	14.64
Passed through 200-mesh	58.38	64.18

TABLE 28.—Composition of Soluble Portion in Percentage of Air-Dried Soils, Nos. 2884 and 2886, as They Passed a 20-mesh Sieve.

	No. 2884		No. 2886	
	Water	Acetic Acid	Water	Acetic Acid
Silicic acid	0.0170	0.0160	0.0292	0.0180
Iron and alumina	0.0035	0.0060	0.0037	0.0040
Manganic oxid (br)	0.0003	0.0130	0.0003	0.0260
Calcic oxid	0.0406	1.0380	0.0439	1.5630
Magnesic oxid	0.0052	0.0440	0.0055	0.0540
Potassic oxid	0.0186	0.0360	0.0324	0.0620
Sodic oxid	0.0011	0.0060	0.0015	0.0040
Phosphoric acid	0.0012		0.0014	

TABLE 29.—Bases Dissolved by Normal Solution of Ammonium Chlorid, and Ammonium Fixed (20-mesh Sieve).

	Previously Treated With Water			
	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0044	0.154	0.0048	0.126
Calcic oxid	0.3680	13.123	0.4208	15.005
Magnesic oxid	0.0294	1.458	0.0337	1.675
Potassic oxid	0.0502	1.066	0.0756	1.605
Sodic oxid	0.0512	1.652	0.0172	0.555
		17.414		18.963
Ammonium		11.779		13.692

	Previously Treated With Acetic Acid			
	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0076	0.198	0.0068	0.190
Calcic oxid	0.3142	12.190	0.3724	13.310
Magnesic oxid	0.0127	0.629	0.0186	0.923
Potassic oxid	0.0263	0.558	0.0225	0.478
Sodic oxid	0.0024	0.077	0.0038	0.121
		13.452		15.022
Ammonium		13.489		14.700

These samples were not previously treated with dilute hydrochloric acid but other samples were and the results were not satisfactory. We endeavored to ascertain the effects of grinding these samples to pass a 200-mesh sieve after previous extraction with water. Results obtained in treatment with ammonium chlorid are given above. The sample was next ground to pass a 200-mesh sieve and treated with ammonium chlorid solution. The following statement is to be compared with the one under subcaption "Previously Treated with Water."

TABLE 30.—Bases Dissolved and Ammonium Fixed in Samples Washed With Water and Ground to Pass a 200-mesh Sieve, in Percentage of Air-Dried Soil.

	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0064	0.168	0.0064	0.168
Calcic oxid	0.3736	13.323	0.4164	14.804
Magnesic oxid	0.0331	1.635	0.0370	1.835
Potassic oxid	0.0642	1.362	0.0852	1.809
Sodic oxid	0.0640	2.061	0.0208	0.671
		18.553		19.287
Ammonium		18.889		18.089

Next, all that portion of these samples that would pass a 200-mesh sieve was washed out and the organic residues washed off as perfectly as possible and the portion remaining, about 40 percent of the original fine earth, was ground to pass the 200-mesh sieve and treated with the ammonium chlorid solution. This residual sample formed a pinkish sand composed largely of felspar, but it showed plainly the effects of weathering.

TABLE 31.—Bases Dissolved and Ammonium Fixed by That Portion of Fine Earth Coarser Than 200-Mesh, but Subsequently Ground in Agate Mortar to Pass This Mesh.

	No. 2884		No. 2886	
	Percent	Mg. Equiv.	Percent	Mg. Equiv.
Manganic oxid (br)	0.0040	0.105	0.0036	0.094
Calcic oxid	0.2324	8.297	0.2026	7.233
Magnesic oxid	0.0191	0.947	0.0133	0.660
Potassic oxid	0.0338	0.718	0.0298	0.633
Sodic oxid	0.0200	0.644	0.0192	0.619
		10.711		9.239
Ammonium		4.372		2.484

This analysis shows that a considerable amount of calcic carbonate remained on this coarser material and also that when ground to pass a 200-mesh sieve this material reacts freely

with ammonium-chlorid solution. While the part that passed the 200-mesh sieve contained almost all that reacted with replacements, there is no sharp dividing line between it and the rest of the soil. The simple grinding can scarcely have produced the same changes that weathering had produced. Some clays show a very great fixing power but grinding and kaolinization are not the same even though the rubbing seemingly must have changed the character of the mineral surfaces presented to the solution. This idea was presented in Bulletin 319, p. 55, under the caption, "The Effects of Grinding," where it was shown that finely ground felspar, when treated with ammonium chlorid and carbonic acid in succession, and when another sample was treated in the reverse order, yielded materially more to the first solvent used than to the second.

FURTHER STATEMENTS OF ANALYSES

While it greatly increased the analytical work and may appear to give too detailed a statement of the results, it is perhaps advisable to include the analysis of the acetate solution in each case. The same may be said of the bases that went into solution in the ammonium chlorid. We need, however, no excuse for presenting these; the former gives us an excellent view of the supply of readily soluble nutrients in the soil and the latter enables us to see how close the ammonium retained or fixed by the soil agrees with the bases released from its more stable portions. Perhaps the latter statement might better be from the finest portions of the soil whose relations to its present fertility may be doubtful but is certainly less intimate than the portion easily soluble in the acetic acid solution. The dividing line is between the easily soluble salts, potash for instance, and those held in the finest particles of the soil, complexes perhaps, which can be set free as exchanged bases by treatment with ammonium chlorid. Here the original structure of the complex is disturbed simply by the substitution of ammonium for the respective bases.

Our primary object was to ascertain in what sense and to what extent these factors may be affected by a 2-year rotation. We especially desired to ascertain the extent to which these exchange values might be affected; in other words, what the effects might be on the complexes. We hoped to find an answer to this in the increase or decrease of the ammonium fixed as exhibited by a considerable number of samples taken in a systematic manner.

POTASH TAKEN UP BY NORMAL AMMONIUM-CHLORID SOLUTION

We treated the samples with dilute acetic acid in a slight excess only to dissolve the calcic carbonate. It was not allowed to stand longer than was judged necessary, but in no case over 2 hours. The calcic acetate formed probably reacted with the soil complexes and perhaps with the mineral particles too. We have shown that calcic chlorid, while a much inferior solvent to ammonium or sodic chlorid, acts very decidedly upon ground felspar. Such reaction may affect the amount of potash taken into solution but probably will not affect the amount of ammonium fixed, or if at all, to only a slight extent. As the calcium solution is not very active, the solution rather weak, the temperature that of the room, and the time never more than 2 hours, the amount of potash taken into solution by reason of such an exchange is probably not sufficient to materially change the natural relations in this respect. I believe that this acetate solution represents constituents held even more lightly than those that have entered into the absorbing complex of the soil. They are practically present in solution and are diffused into the acetate solution. If this be correct we effect a separation of the most readily available ingredients from those which have entered into the complexes and which are perhaps not so available. The sum of these represents the total nutrients, potash for instance, available at the time of sampling.

The potash, soluble in the acetate solution, is probably more variable than that held in the aggregates which seem to be a constant quantity in these samples, if the amount of ammonium fixed may be taken as a criterion. The indications are that the lime and potash replacable by ammonium are really more nearly constant than appears from our tables. I think that the tables indicate this. For instance, the lime is much more abundant in the subsoils, (see the lime in the acetate solutions), and it is difficult to wash 100 grams of soil, containing 5 or more grams of calcic oxid, free from its solution in acetic acid Any error in this direction will express itself in the analysis of the ammonium-chlorid solution. The rule is that the lime in the ammonium chloride solution of the subsoil is uniformly high whereas the ammonium fixed or its milligram equivalent is low.

The ammonium fixed varies with the fineness of the material treated, a fact demonstrated in the cases of Nos. 2884 and 2886 in which the milligram equivalents of the ammonium fixed were increased from 13 to 18 by simply grinding the samples in an agate mortar to pass a 200-mesh sieve, whereas

the original fine earth passed a 20-mesh, but contained 60 percent that would pass a 200-mesh sieve. The grinding increased the milligram equivalents of the ammonium fixed by five points. I believe that grinding really alters minerals though it is difficult to believe that the grinding produces the same effects as kaolinization by weathering.

We were not quite satisfied to leave this question though it seemed to us as positively demonstrated. In order to carry it a little further we washed out of these samples all the material that would pass a 200-mesh sieve, dried the remainder, pulverized it to pass a 200-mesh sieve, and treated this remaining material with ammonium chlorid. The fixation of ammonium by this portion of the samples was represented by 2.5 and 4.9 milligram equivalents. The increase effected by pulverizing the whole sample was 5 milligram equivalents. This was not due to naturally formed complexes.

Exchangeable Bases in These Soils Equal 13 Milligram Equivalents of Ammonium

The ammonium fixed by clays is very much higher even relatively than in the case of these soils. Whatever the fixing factor in these soils may be, the amount is fairly well represented by ammonium having 13 or 14 milligram equivalents. Our results swing a little higher, also a little lower than these figures; the lower figures are found mostly in the cases of the subsoils, possibly due to the variation in the amount of organic matter and clay that may be present.

The change in the color and character of the soil is well marked at the transition from soil to subsoil. We do not feel disposed to attribute the variations in our ammonium-milligram equivalents to errors of manipulation for in cases of repetitions we have failed to change apparently doubtful results. An occasional high result in the case of the bases is due to the difficulty met in washing out large quantities of lime.

In the following tables the even numbers from 2900 to 2959 inclusive, represent soils and the odd numbers, subsoils, but from numbers 3151 to 3168, this is reversed.

The soil is very close to 12 inches deep. The samples represent the soil to approximately this depth and the subsoils to the same depth but we shall give a few smaller sections, 4 and 6 inches, for instance, but these will be designated.

TABLE 32.—Partial Analyses of Soils Nos. 2884 to 2959 and Nos. 3151 to 3170 Stated in Parts per Million.

	Acetate Solution p. p. m.					Ammonium Chlorid Solution p. p. m.					Mg. Equiv.	
*No.	Mn_3O_4	CaO	MgO	K_2O	Na_2O	Mn_3O_4	CaO	MgO	K_2O	Na_2O	Bases	Ammonium
3 Apr. 1925												
2884	130	10380	440	360	60	76	3412	120	263	84	13.65	13.49
2885	180	6170	1180	330	140	8	3248	292	203	24	13.61	11.02
2886	260	15630	540	620	40	68	3724	186	225	38	15.02	14.71
2887	180	64190	1260	330	150	8	3440	320	203	24	15.18	11.40
4 Nov. 1925												
2900	140	1020	290	320	50	24	2944	185	435	47	12.76	13.61
2901	220	64960	1190	410	110	8	3228	308	239	00	13.59	11.73
2902	110	27080	520	490	80	24	3744	145	551	49	15.48	14.16
2903	200	68880	1250	520	120	8	3340	334	257	00	14.15	12.78
2904	70	5320	330	250	60	20	2952	202	415	46	12.63	13.27
2905	180	56920	1170	470	470	44	3304	334	277	4	14.18	10.96
2906	90	14010	480	490	60	12	3564	178	580	42	15.02	13.35
2907	180	64180	1330	520	250	32	3500	371	267	40	13.47	11.83
2908	50	12980	440	350	40	64	3112	152	364	48	12.95	16.22
2909	150	52430	860	550	410	40	3068	267	321	4	13.07	10.10
2910	60	18790	510	610	40	76	3532	162	506	60	13.29	12.78
2911	180	67900	1340	600	280	32	3380	355	278	51	14.68	12.62
2912	100	7640	360	300	60	44	3176	204	305	57	13.44	13.25
2913	140	64900	970	230	480	32	3524	315	211	4	14.69	11.72
2914	20	9620	440	340	280	44	3252	204	372	55	13.72	12.32
2915	190	59360	2750	190	280	24	3312	349	163	63	14.18	10.62

*The even numbers are soils; the succeeding odd number, the corresponding subsoil.

	Acetate Solution p. p. m.					Ammonium Chlorid Solution p. p. m.					Mg. Equiv.	
*No.	Mn_3O_4	CaO	MgO	K_2O	Na_2O	Mn_3O_4	CaO	MgO	K_2O	Na_2O	Bases	Ammonium
2916	90	11460	460	300	170	36	3500	211	356	42	14.53	12.90
2917	150	66280	850	240	440	32	3520	321	202	10	14.99	11.10
2918	160	21880	630	300	440	32	3512	195	348	35	14.46	12.75
2919	180	65160	1350	260	260	28	3516	337	178	32	14.77	11.48
18 March 1926												
2920	12	7442	318	303	42	48	3028	204	391	51	12.95	13.34
2921	80	59790	792	228	72	16	3848	250	180	32	15.52	11.16
2922	40	19320	499	483	24	20	3640	213	465	57	15.26	15.73
2923	80	67870	984	375	82	20	3980	278	235	47	16.30	11.70
2924	22	5565	308	284	45	28	2988	226	415	34	12.86	15.37
2925	90	60760	865	394	73	16	3868	269	258	32	15.86	11.54
2926	90	15700	517	600	90	24	3544	278	464	78	15.34	16.75
2927	100	68470	1118	382	159	20	3860	388	182	59	16.38	17.14
2928	70	12930	485	449	132	24	3160	258	372	80	14.22	14.69
2929	110	56350	934	624	122	20	3352	285	270	76	14.54	14.33
2930	70	22200	550	755	127	20	3636	248	500	100	15.68	18.67
2931	110	69410	1097	465	143	20	3712	324	219	61	15.59	16.38
2932	50	6700	351	339	106	52	3136	220	332	64	13.34	14.43
2933	110	65130	941	196	158	24	4260	330	129	64	17.40	15.31
2934	50	11500	430	362	104	48	3228	210	323	56	13.54	14.99
2935	140	59110	890	252	111	24	3852	297	145	80	15.87	13.53
2936	50	17930	459	316	74	28	3608	240	320	68	15.11	15.32
2937	110	67650	1021	198	127	16	4308	356	128	52	17.64	16.80
2938	30	24650	481	373	143	28	3724	217	317	40	15.26	19.89
2939	90	71320	1089	242	180	80	4532	329	141	60	18.52	17.19

	Acetate Solution p. p. m.					Ammonium Chlorid Solution p. p. m.					Mg. Equiv. Bases	
*No.	Mn_3O_4	CaO	MgO	K_2O	Na_2O	Mn_3O_4	CaO	MgO	K_2O	Na_2O	Ammonium	
27 September 1926												
2940	40	7100	344	380	164	20	3056	208	368	60	12.97	14.79
2941	70	59750	912	391	......	20	5016	249	189	80	19.85	13.39
2942	50	16320	456	589	148	28	3988	197	459	64	16.47	17.79
2943	80	59620	981	510	......	24	5096	308	221	76	19.49	15.94
2944	40	3780	261	275	175	32	3000	232	311	88	12.89	16.39
2945	80	49680	825	323	......	20	4504	191	165	64	17.66	16.70
2946	50	14520	485	498	330	36	3504	198	434	124	14.91	17.16
2947	40	65950	970	341	307	24	4968	274	214	104	19.99	18.23
2948	40	12830	463	329	260	36	3176	223	328	100	13.27	15.08
2949	50	44720	793	490	291	28	3956	178	292	108	16.02	14.80
2950	50	20970	536	606	249	32	3648	215	474	108	15.51	19.61
2951	60	63970	963	426	281	32	4820	295	248	104	19.42	19.05
2952	50	8410	387	302	265	52	3020	207	301	217	13.43	13.92
2953	110	58690	952	180	......	36	3856	200	125	217	15.82	15.08
2954	50	13200	459	325	222	52	3108	208	291	196	13.48	13.48
2955	110	62540	966	244	270	32	3704	185	139	175	15.85	14.38
12 August 1926												
2956	40	16940	503	290	254	48	3460	221	277	164	14.68	16.29
2957	100	67790	1089	168	286	32	4030	217	112	137	15.62	15.68
2958	50	24080	575	383	270	32	3520	198	293	72	14.49	15.07
2959	80	62650	1039	226	286	44	4068	257	148	80	16.46	12.36
5 Apr. 1927												
*3151	30	8400	403	353	105	36	2996	191	362	92	12.80	12.25
3152	50	52955	840	351	110	16	4352	97	219	108	16.87	12.34
3153	25	18160	506	634	120	32	3712	158	472	96	15.43	15.16
3154	35	65770	377	402	115	16	4888	101	224	88	18.61	12.18
3155	20	6550	367	247	145	32	3064	225	308	124	13.17	13.09
3156	45	55790	903	201	95	16	4556	113	164	96	17.52	14.51
3157	65	15575	534	502	119	52	3532	191	420	93	14.02	14.81
3158	60	62040	961	425	132	36	4320	87	229	93	16.73	11.77
3159	55	14770	487	343	135	44	3308	171	316	95	13.90	12.89
3160	60	35625	677	389	119	32	3768	81	240	89	14.73	10.82
3161	30	23270	500	590	183	44	3688	148	418	123	15.30	13.89
3162	50	62375	944	443	159	24	4544	59	214	114	17.40	11.60
3163	35	9120	380	295	145	48	3280	212	320	116	13.94	13.06
3164	45	64115	910	140	190	28	4976	72	132	112	18.94	12.56
3165	40	13560	420	310	140	24	3544	156	320	128	14.60	12.45
3166	55	56345	790	205	135	24	4522	72	146	120	17.28	10.24
3167	30	18185	455	310	165	52	3720	204	300	124	15.76	14.77
3168	30	63170	905	175	165	28	5012	76	132	132	19.05	16.62
3169	55	23550	526	361	175	32	3784	135	331	148	16.18	15.72
3170	55	66310	1059	218	165	20	4588	72	156	124	17.52	17.08

*In this part of the table the odd numbers are soils and the even ones corresponding subsoils.

MILLIGRAM EQUIVALENTS NOT CHANGED BY ROTATION

The samples taken in September, 1926, show higher milligram equivalents than usual, but the significance of this fact is not evident unless it is the result of very high carbon dioxid in the soil atmosphere in August and September of this year. No unusual variation of this sort is shown by the samples of

1927. So far as this feature of our data is concerned our rotation has not affected it in any way. The soda taken into solution by the ammonium chlorid increased decidedly toward the close of 1926 and continued to show this feature in 1927. The same is true of the acetate solution which consistently carries more soda than the ammonium chlorid solution.

In 1927 the potash that went into solution in the ammonium chlorid, especially in the subsoils, was a little lower than previously but the ammonium fixed did not vary in any decided manner. A few samples of September, 1926, were high in this respect but neither the soda nor potash was higher while the lime was.

THE POTASH IN ACETATE AND AMMONIUM-CHLORID SOLUTIONS

The relation between the amounts of the acetate and ammonium-chlorid-soluble potash and the effects produced by the crops is made more evident by the results in Table 33 in which the date of sampling and the crop grown are given. The first pair in each case represents soils and the succeeding pair the corresponding subsoils.

I have not given the manner of sampling though we attach much importance to this operation. All samples were composites of six or more cores so distributed as to represent the plot. There were two plots planted to each crop and four fallow. This accounts for our giving twice as many samples of fallow land as of any one of the cropped plots. The area of each plot was a little less than one-tenth of an acre. The wheat plot was not included in our original scheme and a portion of our fallow was used for these observations. In the table under alfalfa, No. 2908 is the soil from our N. W. alfalfa and 2910 soil from the southeast plot, while numbers 2909 and 2911 are the subsoils corresponding to them, but numbers 3159 and 3161 are soils and 3160 and 3162 are subsoils.

It may be stated, merely as a matter of assurance, that we exercised the greatest care to make every sample, for whatever purpose it may have been taken, thoroughly representative of the plot at the time. We have purposely omitted the details of sampling because we believe that it would add nothing of value to the results.

TABLE 33.—Potash in p.p.m. Found in the Acetic-Acid and Ammonium-Chloride Solutions, and the Milligram Equivalents of Total Bases Found and Ammonium Fixed.

No.	Acetate Solution K_2O	Ammonium Chlorid Solution K_2O	Milligram Equivalent Bases	Milligram Equivalent Ammonium
FALLOW				
*3 May 1925				
2884	360	263	13.7	13.5
2886	620	225	15.0	14.7
2885	330	203	13.6	11.0
2887	330	203	15.8	11.4
4 Nov. 1925				
2900	320	435	12.8	13.2
2902	490	551	15.5	14.2
2901	410	239	13.6	11.4
2903	520	257	14.2	12.9
2912	300	305	13.4	13.3
2914	340	372	13.7	12.3
2913	230	211	14.7	11.7
2915	190	163	14.8	10.6
18 March 1926				
2920	303	391	13.0	13.3
2922	483	465	15.3	15.7
2921	228	180	15.2	11.2
2923	375	235	16.3	11.7
2932	339	332	13.3	14.4
2934	362	323	13.5	14.9
2933	465	219	15.6	16.4
2935	196	129	17.4	15.3
27 Sept. 1926				
2940	380	368	13.0	14.8
2942	589	459	16.5	17.8
2941	391	189	19.9	18.7
2943	510	221	19.5	21.2
2952	302	301	13.4	13.9
2954	325	291	13.5	13.5
2953	180	125	15.8	15.0
2955	244	139	15.9	14.4
CLOVER				
4 Nov. 1925				
2906	490	580	15.0	13.4
2908	350	364	13.0	16.2
2907	520	267	13.5	11.8
2909	550	321	13.1	10.1
18 March 1926				
2924	284	415	12.9	15.4
2926	600	464	15.3	16.8
2925	394	258	15.8	11.5
2927	382	182	16.3	17.1
27 Sept. 1926				
2944	275	311	12.9	16.4
2946	498	434	14.9	17.2
2945	323	165	17.7	16.7
2947	341	214	20.0	18.2
5 April 1927				
3155	247	308	13.2	13.1
3157	502	420	14.0	14.8
3156	201	164	17.5	14.5
3158	425	229	16.7	11.8

No.	Acetate Solution K_2O	Ammonium Chlorid Solution K_2O	Milligram Equivalent Bases	Milligram Equivalent Ammonium
FALLOW				
5 April 1927				
3151	426	248	19.4	19.1
3153	180	125	15.8	15.1
3152	302	301	13.4	13.9
3154	325	291	13.5	13.5
3163	295	214	13.9	13.1
3165	310	320	14.6	12.5
3164	140	132	18.9	12.6
3166	205	146	17.3	10.2
WHEAT				
4 Nov. 1925				
2916	300	356	14.5	12.9
2918	300	348	14.5	12.8
2917	240	202	15.0	11.1
2919	260	178	14.8	11.5
18 March 1926				
2936	316	320	15.1	15.3
2938	373	317	15.3	19.9
2937	316	128	17.6	16.8
2939	242	141	18.5	17.2
12 August 1926				
2956	290	277	14.7	16.24
2958	383	293	14.5	15.07
2957	168	137	15.6	15.7
2959	226	148	16.5	12.4
5 April 1927				
3167	310	300	15.8	14.8
3169	361	331	16.2	15.7
3168	175	132	19.1	16.6
3170	218	156	17.5	17.1
ALFALFA				
4 Nov. 1925				
2908	350	364	13.0	16.2
2910	610	506	13.3	12.9
2909	550	312	13.1	10.1
2911	600	278	14.7	12.6
18 March 1926				
2928	449	372	14.2	14.7
2930	755	500	15.7	18.7
2929	624	270	14.5	14.3
2931	465	219	15.6	16.4
27 Sept. 1926				
2948	329	328	13.3	15.1
2950	606	474	15.5	19.6
2949	490	292	16.0	14.8
2951	426	248	19.4	19.0
5 April 1927				
3159	343	316	13.9	12.9
3161	590	418	15.3	13.9
3160	389	240	14.7	10.8
3162	443	214	17.4	11.6

THE SOIL COMPLEX PROBABLY NOT AFFECTED BY CROPS

The preceding tables show that the milligram equivalents corresponding to the ammonium fixed did not vary much from 13 in 1925, were a little higher in 1926, and dropped back in the spring of 1927. These milligram equivalents are about right; in some cases they have been redetermined without significant change. We offer no explanation for the high results of 1926 except to suggest that they may correlate with high carbon dioxid in the soil atmosphere in August and September of that year. This is the only indication we have that this factor has been affected in any manner by our crops, clover and alfalfa.

THE TOTAL SOLUBLE POTASH DIVIDED INTO TWO PARTS

On the other hand this table presents clearly the division of the potash between the two solvents used, dilute acetic acid and ammonium chlorid, the former acting for not more than 2 and the latter uniformly for 4 hours, though this time is unnecessarily long. The acetic acid solution represents the more readily soluble potash and the ammonium chlorid the less soluble, i. e., that which was held in the absorbing complex as exchangeable potash. Considering the nature of the material operated with, the range of the potash dissolved out of the samples, after previous treatment with acetic acid, is really very limited in the soils and subsoils respectively. If we compare, however, the amounts dissolved by the respective solvents, the advantage is rather strongly in favor of the acetic acid, the aggregate difference being about 200 p. p. m. for both the soils and subsoils.

The following tabular statement serves to bring this out more clearly. The figures are the average of all samples treated; for instance, 379 p. p. m. is the average amount of potash extracted from the fallow soils by acetic acid added in slight excess over the amount calculated as necessary to dissolve all of the calcic carbonate present. This was calculated from the amount of carbon dixoid found in each case by a direct determination. The time of digestion was 2 hours. The ammonium chlorid was used in normal solution and the time of digestion was 4 hours.

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*Samples 2884-5-6 and 7 were taken at beginning of experiment. Numbers 2884-5 represent soil and subsoil of north half and numbers 2886-7 the south half of the whole plot. Footnote for p. 78.

TABLE 34.—Potash Dissolved Out of Samples by Acetic Acid and Ammonium Chlorid in Succession, in Parts per Million.

	Soils	Subsoils		Soils	Subsoils
FALLOW			CLOVER		
Acetic acid	379	307	Acetic acid	407	392
Ammonium chlorid	324	200	Ammonium chlorid	412	225
Total	703	507	Total	819	617
WHEAT			ALFALFA		
Acetic acid	327	242	Acetic acid	503	399
Ammonium chlorid	285	150	Ammonium chlorid	328	208
Total	612	392	Total	831	607

Heretofore we have paid particular attention to the ammonium-chlorid solution and the milligram equivalents as giving us an idea concerning the absorption complex existing in this soil, also the extent to which it is affected by the crops grown. We obtained no more than a suggestion that some influence had been exerted by them in this direction by certain crops in September, 1926. This was a suggestion only and I consider it of little weight because the samples from the fallow plots show a tendency in the same direction.

The Acetic-Acid-Soluble Potash Increased by the Crops

The acetic-acid solutions show much more decidedly that the amount of soluble potash in the soil is affected by the crops. The wheat crop shows a depression in that that went into solution in the acetic acid and also in that that went into solution in the ammonium chlorid. The total is practically 100 p. p. m., below the total of the fallow. This is true for both the soil and subsoil. The clover and alfalfa each increased the total soluble potash over that in the fallow by about 100 p. p. m. in both the soil and subsoil. This difference is almost wholly confined to the potash soluble in the acetic acid.

A Complex Exists in This Soil

Our conclusion from this portion of our investigation is that there is a definite complex in our soil which has a capacity for exchangeable ammonium corresponding to about 13 milligram equivalents and that this is the same whether the soil is used as gathered and air-dried or previously washed with water or treated with dilute acetic acid in the manner stated.

THERE ARE SALTS OR SALT SOLUTIONS INDEPENDENT OF THE COMPLEX

There are salt solutions or their equivalents in the soil independent of the complexes and these are easily soluble in the acetate solution. While the complex is not modified by the crops, this soil solution may be improverished by the crop as in the case of wheat, or it may be enriched as in the cases of clover and alfalfa, taking the potash as our criterion.

While the potash is only one factor, it is probably the most important one; it is certainly so in quantity and others have shown that the volume of crops correlates more closely with this than with any other factor of fertility.

SILICIC ACID, ALUMINA, ETC., OMITTED FROM STATEMENTS

In our tabulated statements we have omitted the silica, iron, alumina and the phosphoric acid in most cases. The silicic acid dissolved out of these soils by dilute hydrochloric acid, 1:2 of water, on treating them for a very short time, 3 to 10 minutes, is not far from 0.1 percent of the soil and the amount separated that may subsequently be dissolved by treating the residue with sodic carbonate is only a few hundredths of one percent. Apropos to this last operation, it must be remembered that it is not a difficult matter to bring some quartz into solution.

HYDROCHLORIC ACID DESTROYS THE SOIL COMPLEX

The treatment with hydrochloric acid as previously given is, on the other hand, sufficient to change the replacement ratios between the bases removed and the ammonium absorbed. It practically destroys them, i. e., it destroys the absorbing complexes in this soil. This statement is based upon the results obtained in fifteen cases, using an excess of 1:2 acid. The complex does not seem to contain any considerable amount of silica.

The hydrochloric acid dissolves the iron and alumina rather abundantly, about 0.5 percent, including phosphoric acid, which it dissolves freely.

Attention was directed to the easy solubility of the phosphoric acid in this soil in Part I of this investigation, Bulletin 319. Fifty percent of the total phosphoric acid present went into solution in this weak acid, approximately 10 percent in 10 minutes, using 150 cc. acid to 100 grams of soil. The acetic acid dissolved only about 0.02 percent of silica and usually between 0.01 and 0.02 percent of iron and alumina together; the acid was only slightly in excess of that necessary to dissolve the calcic carbonate present.

PHOSPHORIC ACID SOLUBLE IN ACETIC ACID

The phosphoric acid that went into solution in the acetic-acid solution was determined in a few cases; it varied up to 60 p. p. m. of the air-dried soil, but was never absent; it was present also in the aqueous solutions.

MOUNTAIN MASSES AND SOILS ARE DIFFERENT

The study of our problems as presented at this station as distinguished from some other parts of the state, has led us to emphasize the importance of felspar and its deportment toward solvents, especially toward carbonated water. We have in several publications called attention to the character of our mountain waters and these are the waters we use for irrigating, which owe their mineral contents very largely to the solvent action of natural waters on this mineral. Mica also contributes, but this mineral, while not absent, is not abundant in the soils like felspar. The salts in solution are carbonates with free silicic acid and very small amounts of chlorids and sulfates. The principal carbonates are those of calcium and potassium. These are removed when they come in contact with the soil. Mineralogically, our soils differ little from the mountain masses and in the main the reactions toward water are alike. The soils and mountain masses are not identical, the soils retaining the decomposition products brought about by the action of air, plants and weathering, which are washed off of the mountain masses.

The lime in these soils is continually playing so big a part that we simply have to accept it as a permanent condition. Our analyses show that our soils contain from 0.5 to 1.5 percent of lime, CaO. From this fact, as well as from the view of the crops, potash is the important element in our problem.

PHOSPHORIC ACID NOT INVOLVED IN CROP ROTATION

The phosphoric acid in this soil is 0.186 percent and all of the experiments that we have made by applying it show that its addition does not produce direct crop results, so there are reasons for believing that this is not a factor in the benefits observed from a crop rotation. This may be due to its ready solubility. The acetic-acid solutions contain up to 42 and 60 p. p. m. and carbonated water 30 p. p. m. in the presence of 10,110 and 15,-340 p. p. m. of calcic oxid in the form of bicarbonate. The aqueous extracts also carry it in solution. Many examples of this fact are given in Bulletin 22 of the Bureau of Soils, United States Department of Agriculture, but not in the presence of so much lime which is considered to preclude its remaining in solution.

I do not know how dilute a phosphoric-acid, soil solution will suffice for the growing of good crops. I have seen the statement that plants could supply themselves with a sufficiency of phosphoric acid from solutions containing one part per million. This soil would maintain a stronger solution than this. We found in an aqueous extract 14 p. p. m. P_2O_5, and higher figures are given by others for some soils. The amounts given above, 60 and 42 p. p. m., for the acetic acid solution and 30 p. p. m. for carbonated water, justify us in omitting this phase of the question in our investigation.

According to our view of the problem we are justified in confining ourselves so far as the mineral constituents involved in crop production are concerned, to the potash supplied.

The data already given show that in the cases of clover and alfalfa, the occupancy of the land by these crops increased the soluble potash, K_2O, in the top 2 feet of the soil by 800 pounds per acre.

INVESTIGATION OF WATER-SOLUBLE POTASSIUM

We arrived at a similar conclusion as the result of a different line of investigation, the principal one in this work, which had for its specific object to ascertain whether the soluble potassium was increased.

We showed in the first section of Bulletin 319, as the results of a preliminary series of observations which extended over three seasons, that the soil atmosphere in fallow ground carries about 35 parts per 10,000 of carbon dioxid but under clover it carried five times as much. In the second section of the same bulletin we showed that carbonated water acted on felspar removing principally potash, K_2O, up to 720 p. p. m. if the mineral were finely ground. The fallow ground is acted on at all times by an atmsophere carrying 35 parts carbon dioxid per 10,000 but that planted to clover by one five times richer; the latter should also be richer in soluble potassium, provided the clover did not use up all of the excess. Land planted to alfalfa should be at least as rich in soluble potassium as that planted to clover, for while it is a very heavy feeder on potassium, it evolves an immense amount of carbon dioxid and maintains the evolution throughout the year. We shall later set forth the details in regard to this point.

The carbon dioxid in the fallow ground kept free from all visible vegetation was undoubtedly due to the soil population. If these factors were equally active in the clover soil we must have to credit the clover with four-fifths of the total carbonic acid found, but the source of the carbon dioxid does not

affect the question as here presented; if the carbon dioxid is continuously more abundant in one soil than in another and if the carbon dioxid and water will continuously act on the felspar in these soils to liberate potash, the one more liberally supplied with carbon dioxid ought, if no disturbing factor enters, be the richer in soluble potassium.

Carbon Dioxid in Soil Atmosphere Not Due to Soil Population

It is neither proved nor disproved that the soil population is equally active in the fallow and clover ground. How these soil organisms and the clover agree I do not know, but some of them agree finely. I doubt whether this feature is as important as I at one time thought it was but it is not negligible. My impression is that a general opinion obtains that the soil population is accountable for the larger portion of the carbon dioxid in the soil atmosphere and for some favorable changes such as the solution of phosphoric acid. Some of these things may be so but they are not all true. The data given lead us to credit at least four-fifths of the total carbon dioxid found in land planted to clover to the plants themselves.

We have intimated that the clover may stimulate the growth of the soil population followed by a proportionate increase in the carbon dioxid produced. This may be true too, but when the clover was cut in the series given in Bulletin 319, the carbon dioxid dropped suddenly, showing that the large quantity of carbon dioxid in the soil atmosphere depended upon the vegetation of the clover and not upon the soil population. When the clover grew again the carbon dioxid increased again. The fall in the quantity of carbon dioxid in the soil atmosphere was so sudden and so low that we are inclined to think that the soil population was not as vigorous in the clover land as in the fallow. The observations on the amount and variation of carbon dioxid in the soil air have been greatly extended in the main series and made to include clover and alfalfa as the main members and wheat and maize as subordinate members. Mr. Douglass has made a great many observations in this connection and his data will be presented later.

Respiration of Alfalfa Roots

As we intended that alfalfa should be the representative of leguminous plants in a rotation which purpose clover fulfilled in the preliminary series, we endeavored to obtain an idea of the rate of respiration of alfalfa roots and included clover roots. For this purpose we gathered the roots and cut out sections 7

inches long and weighing 34.5 grams while perfectly fresh. The roots were measured and their superficial area ascertained to be 31 square inches. In the first experiment the roots were used just as they were brought in from the field without washing, sterilization or sealing of the cut ends. The result of the first experiment was 32.3 cc. of carbon dioxid in 18 hours.

In the second experiment, at the suggestion of Dr. Durrell, I sealed the cut ends with vaseline and sterilized the roots with a mercuric chlorid solution. The roots used were smaller and presented more surface. The result was 52.8 cc. in 18 hours.

RESPIRATION OF CLOVER ROOTS

A similar experiment was made with clover roots, observing the precautions of the second experiment. Forty grams of roots were taken and the experiment continued for 23 hours. The volume of carbon dioxid under standard conditions was 104.1 cc.

These experiments show that the excretion of carbon dioxid from the roots of these plants is sufficient to account for very large amounts of the gas. The growing plant must be very much more active than these roots if the rapid increase of carbon dioxid in the soil with increased vegetation be taken as a guide.

GREAT MASS OF ROOTS IN THE SOIL

We used a few roots presenting a few square inches of surface and the mass of the root itself was the only source of carbon dioxid. The stand of alfalfa was a young one and was a good stand; this means that there were probably ten plants to the square foot of land. The length of each root was not less than 6 feet. We have on two occasions endeavored to dig out alfalfa roots in this land. We cut off the roots 11 feet below the surface and they were still strong roots. I do not know how long they were. The alfalfa root does not spread very much, but very much more near the extremity than near the crown, where it usually consists of a simple taproot. The amount of carbon dioxid excreted by such a system even though we should discount our results greatly, would be sufficient to account for all of the carbon dioxid that we have found without the aid of the soil population. We have in no way considered the amount diffused from the surface of the soil. This is undoubtedly a very large amount but not large enough to reduce the amount remaining even at a shallow depth to conceal the results that we wish to study.

The growing plants are much more active than mutilated ones; this is shown by the falling off of carbon dioxid after the cutting of the plants and its increase as new shoots are put out.

Vigorously growing plants eliminate more carbon dioxid than slowly growing ones; this is shown by the response made in the increase of carbon dioxid after an irrigation which is much less in the fallow than in the cropped land because the soil population can approach their maximum activity with less water than clover or alfalfa.

Carbon Dioxid Excreted by Leaves and Stems Not Involved

The carbon dioxid excreted by the aerial portion of the plants does not seem to enter into our question as it apparently diffuses into the atmosphere so rapidly that none of it accumulates at the surface of the ground, even when covered by a heavy growth of plants. The only accumulation at this point has been under coverings of heavy canvas to prevent free diffusion out of the soil, into the atmosphere.

Wheat Different From Clover and Alfalfa

The presence and source of this greatly increased amount of carbon dioxid in cropped soils have been established and shown to be the case throughout the year in the case of clover and alfalfa. Wheat has a different history; the spring wheat that we used completed its life course from planting to maturity in about 120 days. It increased the carbon dioxid very largely during its vegetative period and the carbon dioxid then declined. The dead wheat plants or the parts of them remaining in the soil doubtlessly furnished some carbon dioxid as they fell prey to the soil population. We cannot follow the effects of this crop further than we have already given it.

We have some data concerning these effects; the nitric nitrogen in the soils is thoroughly exhausted and requires several months to be replaced; the total nitrogen is diminished rather than increased; the potash is used up to a greater extent than it is liberated—at least this appears to be the end result. We have at no time attempted to study its effects upon the amount of phosphoric acid in the soil. We have reversed this and studied the effects of phosphoric acid applied as superphosphate to this crop, but its effect upon the volume and character of the crop was nil, even when we applied as much as 60 pounds of soluble phosphorus per acre. The story of clover and alfalfa is a different one; they grow throughout the season and live through the winter, maintaining the carbon dioxid at all times above that in fallow ground.

In Bulletin 319 we showed that carbon dioxid in water eliminates potash from felspar even when other salts are absent but the addition of them increases its action. Our data presented in connection with the composition of the acetic-acid solution of this soil show that the wheat depressed the potash while the clover and alfalfa increased it; this is true particularly of the portion that went into solution in the acetic-acid solution or was not contained in the aggregates. The portion that went into solution in the ammonium-chlorid solution after previous treatment with acetic acid was not materially affected. In the case of the alfalfa this increase was 100 p. p. m. in the subsoil and rather more in the soil. As our soil weighs a little more than 1,000,000 pounds per acre foot, this means an increase of 800 pounds of easily soluble potash, K_2O, per acre taken to a depth of 2 feet.

We attacked this question in another way after we had learned of the great and consistent excess of carbon dioxide in the soil air under the clover and alfalfa. The suggestion follows from our results given in Bulletin 319, i. e., if carbon dioxid and water bring potash into solution when in contact with felspar, then the water-soluble potash ought to be more plentiful under clover and alfalfa than in fallow land because the carbon dioxid is higher at all times. The potash determinations may not be correct but they will be as nearly so for the fallow as for the alfalfa, and the results will be comparable.

We adopted the method proposed by the Bureau of Soils of the United States Department of Agriculture, being convinced that by adhering to a definite procedure the results would be conclusive so far as our purposes were concerned. We certainly do not exhaust the soil of its soluble potash by the 3 minutes rubbing and 30 minutes standing; this is not claimed for the method, but by adhering to a definite treatment the results will correspond closely to the relative amounts of easily soluble potash in the different samples and this is what we wish to ascertain.

While our data give us some opportunity to observe the effects of the growing plants upon the amount of soluble potassium in the soil, to observe the effects of irrigating the crop, also of cutting it, it was not our purpose to study these nor is it our purpose to comment on them. The only purpose that we had in view was to establish the effects of the crops upon the supply of soluble potassium through the increased amount of carbon dioxid maintained in the soil air throughout the season by the clover and alfalfa. In this respect they differed from the wheat

which maintained a large amount in the soil air for the short period of its active vegetation only.

The amounts of potash obtained in this manner can represent only the difference or residual potash not used by the plants in their growth. The amount used by alfalfa is large and in our case we removed the hay from the plots. This was not a negligible quantity but we did not set out to keep account of potash used. An average crop of alfalfa hay, three cuttings, will remove about 200 pounds of potash, K_2O, annually. A full crop on our college farm removes at least 225 pounds. This is a real factor in the potash problem but we have not attempted to take it into account though our crops were certainly as good as full crops. Any increase given for the total potash in the alfalfa land per annum is by this much too small.

Our piece of land, about one-half acre in area, was divided by fallow strips running north and south, also east and west, into four sections of a little less than one-tenth of an acre each. The northwest and southeast sections were planted to alfalfa and the northeast and southwest sections to clover, and portions of the dividing area were used for small plots of wheat or corn.

Plots Are Not Uniform

Superficially this land appears to be of uniform quality; it is far from being such. In some respects these differences have been troublesome. The north and south halves of the whole piece, from the standpoint of composition, are different and the respective sections differ from one another. In regard to the potassium extracted by the method given, the north half of our west alfalfa plot was at all times and for all depths sampled, richer than the south half and also richer than the other portions. We further find a variation from time to time in the same section. We did not expect to find the soluble potassium a constant quantity in any plot but it is very proper that these variations should be mentioned if not emphasized.

The alfalfa designated west alfalfa, was accordingly in the northwest corner and the east alfalfa in the southeast corner of the piece of land. The designation south and north in the tables signifies the respective halves of the plot. A glance at the table giving the potassium in the west plot shows the striking and persistent differences of the two halves. Mr. Vail, who made all of these potassium determinations, varied his lines of sampling in order to establish this difference. The table shows that these differences persist in all cases sampled. The samples represent the surface 6 inches and the second 6 inches of the second

and third foot respectively. The latter depths were chosen because they represent the 6 inches of soil lying just above our lysimeters.

SOLUBLE POTASSIUM VARIES WITH GROWTH OF PLANTS

Shortly after cutting the crop, also after irrigating the plots, there seems to be an increase, in the case of the alfalfa, in the water-soluble potassium. The increased moisture and renewed growth of the plants with a consequent increase in the carbon dioxid are the contributing causes. There are sharp variations in the results with the clover ground which are probably influenced by the maturity of the plants. We see a sharp decrease on 22 June in the plot not irrigated, and on 25 June, in the irrigated plot. The difference in the date was due to irrigation and the relative difference in the development of the plant.

The decrease after 13 September was general and followed the plowing-under of the crop and consequent changes in the soil conditions. It was not our object in making these determinations to study these features but the broader one of the differences in the effects produced by our crops, particularly clover and alfalfa, upon the amount of soluble potassium compared with that in the fallow. We assume that the biological factors other than the crops are essentially the same throughout the piece of land. We think that they are modified but believe that the conditions in the fallow land are in the main more favorable for the soil population than in the cropped land.

THE IRRIGATIONS AND CUTTINGS OF 1927

The plots on the west side were irrigated 27 May and 6 July, 1927, but the east side was not irrigated till 9 August; the whole piece was irrigated 9 September and the crops plowed under on the thirteenth. The water was withheld from the east side till 9 August to see what effect it would produce on the amount of carbon dioxid developed.

The first cutting of 1927 was made 27 June, the second 29 July and the third growth was plowed under on 13 September. We had snow and rain on 26 September, 13 days after the plowing.

The following tables give the soluble potassium found in fallow, clover and alfalfa plots from 20 May, 1927, till the end of November when the frost interfered with our sampling.

TABLE 35.—Soluble Potassium, K, in Fallow, Clover and Alfalfa Plots From May 20 Till End of November, 1927.

Soluble Potassium K, in Fallow Soil, Parts per Million, 1927.

	WEST PLOT							EAST PLOT					
Depth	0-6 In.		19-24 In.		31-36 In.		Depth	0-6 In.		19-24 In.		31-36 In.	
Date	S	N	S	N	S	N	Date	S	N	S	N	S	N
20 May	28.9	24.9	11.0	20.3	11.0	13.1	27 May	22.5	36.9	14.3	18.6	18.6	19.2
3 June*	32.4	25.5	26.3	52.7	36.7	37.1	8 June	20.1	15.8	10.3	8.4	7.5	11.1
11 June	16.9	16.9	8.8	15.9	8.1	8.8	15 June	21.7	24.9	13.1	7.7	9.1	7.7
18 June	21.3	30.8	6.8	13.0	7.1	8.1	22 June	14.1	16.6	12.9	10.4	16.3	15.9
25 June	35.1	36.4	17.1	32.3	18.4	17.6	29 June	19.7	20.4	15.4	15.4	15.8	17.3
2 July	30.2	33.9	15.0	21.3	16.1	16.9	6 July	26.9	24.9	10.9	10.1	12.2	13.8
9 July	25.9	26.5	12.6	25.3	16.4	18.2	13 July	19.3	17.1	14.3	13.3	13.8	14.8
16 July	24.9	25.3	18.9	26.9	21.3	26.3	20 July	27.8	23.8	22.8	18.6	24.1	21.8
23 July	32.5	28.0	19.8	35.0	17.1	20.5	27 July	17.2	15.9	23.9	25.3	30.9	30.8
30 July	11.5	15.7	25.6	31.7	27.9	14.5	3 Aug.	34.2	33.8	13.0	17.5	15.5	15.5
6 Aug.	43.9	31.2	22.8	31.2	21.9	26.8	10 Aug.	48.3	42.5	17.1	16.0	20.1	24.2
13 Aug.	51.4	41.8	19.9	25.0	15.9	16.2	17 Aug.	24.7	22.7	10.8	9.8	12.4	14.4
20 Aug.	50.8	48.3	23.1	27.8	23.8	24.9	24 Aug.	27.6	26.0	10.9	9.9	15.5	17.6
27 Aug.	67.9	63.9	18.6	32.0	21.2	19.5	31 Aug.	28.5	25.0	11.2	10.2	11.5	10.8
3 Sept.	24.5	25.5	9.9	12.1	19.2	17.0	28 Sept.	22.7	18.3	15.1	9.9	15.3	14.9
23 Sept.	9.9	9.3	25.8	20.7	20.7	16.5	8 Oct.	26.1	33.3	6.9	6.4	6.5	7.7
3 Oct.	14.6	18.7	22.0	30.4	19.6	21.5	20 Oct.	32.9	27.6	11.8	16.4	6.2	4.9
14 Oct.	35.2	29.6	12.2	16.1	8.7	7.9	28 Oct.	9.9	9.3	4.4	4.5	19.1	16.5
25 Oct.	29.1	29.1	3.3	4.0	4.4	7.4	4 Nov.	19.8	20.6	10.8	9.3	7.6	6.6
1 Nov.	27.1	24.5	6.5	5.4	8.4	8.8	12 Nov.	13.1	11.3	11.1	8.1	9.7	9.5
8 Nov.	15.5	17.1	13.7	15.1	14.2	14.1	18 Nov.	15.5	12.3	16.5	9.1	15.4	20.7
15 Nov.	12.4	14.3	7.4	9.9	24.7	17.9	28 Nov.	17.3	17.5	9.9	7.0	13.6	9.3
22 Nov.	12.9	12.7	8.1	17.2	12.7	16.2							
Average	28.5	27.4	15.4	22.7	17.2	17.2		23.2	22.6	13.1	11.7	14.4	14.8

Soluble Potassium, K, in Soil under Growing Clover, in Parts per Million, 1927.

	WEST PLOT							EAST PLOT					
Depth	0-6 In.		19-24 In.		31-36 In.		Depth	0-6 In.		19-24 In.		31-36 In.	
Date	S	N	S	N	S	N	Date	S	N	S	N	S	N
20 May	90.4	69.6	43.3	29.0	24.0	23.6	27 May	26.5	32.3	16.2	64.8	17.1	59.6
3 June	44.0	44.2	44.1	50.2	22.5	24.4	8 June	14.3	19.4	7.9	29.3	5.6	14.5
11 June	42.7	38.2	26.4	17.9	16.1	17.0	15 June	16.4	15.3	9.7	20.2	13.7	21.0
18 June	35.9	30.5	17.9	22.2	14.9	12.5	22 June	8.2	11.5	8.1	48.8	7.9	29.7
25 June	18.4	17.1	13.1	7.5	31.2	20.6	29 June	22.1	26.9	15.4	52.8	9.9	24.9
2 July	33.2	31.9	25.3	26.3	17.4	17.8	6 July	11.8	11.9	5.8	22.9	12.9	41.1
9 July	56.9	38.2	36.6	18.6	22.9	18.7	13 July	15.9	25.9	9.8	33.4	8.6	20.6
16 July	55.5	41.6	38.1	26.5	21.5	19.3	20 July	22.3	39.1	15.6	57.2	18.8	40.5
23 July	30.3	23.9	29.5	16.6	19.3	16.6	27 July	20.9	20.3	15.3	38.5	10.9	31.4
30 July	16.3	15.3	13.6	7.5	20.0	16.8	3 Aug.	17.1	21.2	11.3	45.8	11.6	50.4
6 Aug.	47.1	50.5	21.1	16.0	25.8	23.2	10 Aug.	27.3	58.2	15.8	54.9	25.7	67.1
13 Aug.	73.8	60.4	31.0	26.2	22.9	18.7	17 Aug.	20.5	42.4	16.3	52.7	30.0	78.8
20 Aug.	53.9	50.8	46.6	30.5	43.2	31.1	24 Aug.	31.4	30.6	10.7	52.6	15.4	61.1
27 Aug.	52.0	38.6	31.3	19.3	21.2	25.1	31 Aug.	17.4	18.8	8.4	28.8	9.4	15.7
3 Sept.	39.4	35.2	19.3	15.7	10.8	10.6	28 Sept.	14.2	15.4	8.0	19.3	9.1	13.5
23 Sept.	36.3	34.9	44.1	22.6	9.3	8.6	8 Oct.	18.7	32.1	15.5	40.1	7.7	10.2
3 Oct.	31.7	22.9	21.1	13.5	13.8	11.6	20 Oct.	6.8	7.9	21.8	41.6	17.5	22.0
14 Oct.	53.3	73.5	46.5	56.7	13.8	10.6	28 Oct.	11.8	6.6	9.9	42.1	9.9	36.8
25 Oct.	42.6	34.8	52.4	27.4	11.8	11.8	4 Nov.	7.5	16.4	30.3	73.4	24.9	67.9
1 Nov.	66.7	54.2	46.4	37.3	13.4	10.7	12 Nov.	23.8	30.5	18.6	41.4	6.6	11.8
8 Nov.	24.5	16.5	16.1	7.9	8.9	8.9	18 Nov.	13.5	20.4	12.4	17.1	7.9	8.1
15 Nov.	43.1	42.2	36.9	25.6	20.8	22.2	28 Nov	14.6	18.9	12.3	21.2	7.1	8.3
22 Nov.	38.8	30.5	14.9	7.7	9.9	10.0							
Average	44.6	38.8	31.1	23.0	18.9	17.0		17.4	23.7	13.4	4.10	13.1	33.5

Soluble Potassium, K, in Soil under Growing Alfalfa, in Parts per Million, 1927.

	WEST PLOT							EAST PLOT					
Depth	0-6 In.		19-24 In.		31-36 In.		Depth	0-6 In.		19-24 In.		31-36 In.	
Date	S	N	S	N	S	N	Date	S	N	S	N	S	N
30 May	43.1	49.7	27.5	109.2	19.4	86.2	27 May	88.7	49.4	53.8	43.6	23.2	16.0
3 June	33.9	43.1	41.4	93.7	25.5	87.7	8 June	44.4	33.5	31.9	29.2	8.5	15.6
11 June	17.0	27.5	36.1	72.7	8.7	38.1	15 June	19.6	21.1	11.5	15.7	17.2	16.8
18 June	21.4	23.3	19.4	23.3	14.0	53.4	22 June	43.5	27.0	18.6	22.4	11.6	12.9
25 June	21.8	59.7	14.9	86.5	20.6	42.2	29 June	89.3	40.3	40.7	36.9	20.2	17.2
2 July	30.5	41.9	32.8	65.3	29.3	34.1	6 July	60.5	39.4	38.4	31.6	14.5	15.6
9 July	31.9	37.9	25.3	86.8	14.0	57.5	13 July	52.3	42.6	26.3	24.9	11.3	11.3
16 July	27.0	51.9	22.1	69.9	12.9	64.8	20 July	69.3	52.4	56.6	31.8	24.8	20.1
23 July	37.8	39.5	49.5	89.7	17.9	49.6	27 July	59.0	40.9	33.9	24.1	11.7	9.2
30 July	18.1	23.4	33.6	71.3	7.9	28.2	3 Aug.	70.8	67.3	40.8	37.3	20.3	15.6
6 Aug.	43.4	64.7	45.7	75.1	18.2	51.8	10 Aug.	77.5	58.7	39.4	79.3	38.7	40.1
13 Aug.	40.6	69.8	30.1	108.7	29.9	115.3	17 Aug.	75.1	58.9	47.5	53.4	26.0	19.7
20 Aug.	34.8	54.6	21.3	88.1	22.1	93.3	24 Aug.	69.8	43.6	38.7	32.7	20.6	17.5
27 Aug.	34.4	56.8	22.4	85.9	40.1	129.2	31 Aug.	32.1	61.2	16.4	10.2	18.3	14.8
3 Sept.	14.0	23.4	45.9	72.2	40.7	62.8	28 Sept.	58.0	40.9	34.3	51.5	11.5	11.9
23 Sept.	35.2	49.0	37.5	103.0	18.8	83.7	8 Oct.	57.1	53.6	36.8	37.6	27.1	18.8
3 Oct.	25.7	63.7	21.7	101.9	16.7	34.9	20 Oct.	30.4	20.4	19.6	16.1	10.4	13.1
14 Oct.	13.0	16.4	19.1	40.0	21.0	54.4	28 Oct.	27.9	15.0	20.0	19.2	10.3	11.3
25 Oct.	18.7	34.2	20.1	73.3	15.3	72.7	4 Nov.	33.5	49.0	24.3	14.0	25.7	19.4
1 Nov.	6.4	10.1	10.0	31.8	26.1	30.9	12 Nov.	59.2	19.6	49.7	35.0	13.3	6.2
8 Nov.	17.4	20.3	18.1	41.5	9.2	28.1	18 Nov.	70.0	34.5	94.8	26.2	14.1	6.4
15 Nov.	10.2	21.4	13.6	52.1	17.2	42.9	28 Nov.	12.9	7.8	9.9	5.4	27.1	25.6
22 Nov.	11.1	14.4	20.1	42.8	15.6	34.0							
Average	25.5	39.0	27.3	73.3	20.0	60.0		54.6	39.9	35.6	30.8	18.5	16.1

These tables have been put into the form of graphs for two reasons; to present at a glance the general facts and to enable one to make a comparison with the carbon dioxid found on any desired date.

The soluble potassium in the different plots varies, also the north and south halves of the plots vary, and the samples taken at different depths do not run parallel. This is quite marked in our west alfalfa plot. There is, however, a general parallelism between the amount of soluble potassium and that of the carbon dioxid found in the different plots. To show this was the purpose of the determinations and is perhaps as much as we could expect our methods to demonstrate.

The general parallelism of the soluble potassium at different depths is best shown by our east fallow plots but even in these we observe at the end of July that the 6-inch samples give a descending curve whereas the other depths give an ascending one. The difference is about 15 p.p.m. While some of the variation may be due to sampling and some to the method of analysis, I do not believe that these explain the difference. In the fallow plots, we do not find the high and low soluble potassium in the separate plots on the same date. The range is larger for the 6-inch samples in the fallow than for any other depth; this is

not true of the clover and alfalfa plots. The other depths in the fallow are quite uniform.

The general and important fact is that there is very decidedly more soluble potassium in the clover and alfalfa soils than in the fallow ground. Further, this amount varies with the carbon dioxid. After an irrigation there is a strong development of carbon dioxid due to the accelerated growth of the plants, and there is also an increase in the soluble potassium present. There are apparent exceptions to the last statement, i. e., in the alfalfa plot that was not irrigated till 9 August but was cut 30 July, 1927. We have a new growth started after cutting and the carbon dioxid began to increase; this was maintained by the irrigation applied 9 August; in this case the soluble potassium increased till 24 August, when it began to fall. Again, there is a fall in the alfalfa land that was regularly irrigated, setting in about 23 July.

We hesitate to advance an explanation for the deportment of the soluble potassium in the 6-inch samples from the fallow plots but it may be due to a wet period at the end of July. We have a similar rise in the unirrigated plot in June, also following a series of light rains. The rise is much more pronounced in the irrigated plot.

POTASSIUM DECREASED AFTER PLOWING

The decrease in the soluble potassium in the soil after the land was plowed on 13 September is marked but it is common to the cropped and fallow land though greater in the cropped land. The fallow land was occupied by the soil population alone, the clover plots by a comparatively shallow-rooted but vigorously growing crop and the alfalfa plots by a deep-rooted one, yet they all deported themselves in the same manner. We have three depths; the first, fourth and sixth 6 inches of the soil. The first 6 inches of the fallow were uniformly richer than the sixth 6 inches until after the plowing when they fell to nearly the same amount. We observed in our preliminary series of carbon-dioxid determinations that, while the moisture did not make a great difference in the amount of carbon dioxid in the atmosphere of the fallow ground, the temperature did; an increase of temperature increased the carbon dioxid and a few cloudy and cooler days depressed it greatly. The season may have brought about part of this change in the soluble potassium in our fallow by suppressing the evolution of carbon dioxid on which the amount of soluble potassium largely depends. Our west clover plot shows the least change and the soluble potassium keeps up pretty well.

FALL OF SOLUBLE POTASSIUM NOT ANTICIPATED

This fall in the soluble potassium was not anticipated for we thought that the weather was still warm enough to induce the crop plowed under to ferment quickly with a strong evolution of carbon dioxid, which though it might diffuse out of the ground rapidly at this depth, would suffice to bring more potassium into the soluble form. The clover plot on the west side alone gave results lending support to this view and this is not very pronounced. This falling off of the soluble potassium raised the question whether it would go into solution if we used carbonated water instead of distilled water free from carbonic acid, a condition that we had zealously observed. The procedure was not changed in any other respect. Four samples were selected that had given only small amounts in the regular analysis.

The original results were:

10.8 and 9.2 p.p.m. soluble potassium
7.6 and 6.6 p.p.m. soluble potassium

With carbonated water these became:

22.0 and 17.8 p.p.m.
16.5 and 14.0 p.p.m.

The difference is over 100 percent.

Our inference is that the fall in soluble potassium was due to the cessation of the active excretion of carbon dioxid by the crops. The falling temperature of the season would have had some effect in the same direction, as it tends to depress the evolution of carbon dioxid in the soil. The plowing up of the crops stopped the excretion of carbon dioxid and the cool weather tended to do the same thing. We expected a freeze in late September that would kill the alfalfa roots. We did not have a sharp freeze and the weather continued warm and the alfalfa continued to grow to an undesirable extent.

The averages of all the potassium determinations made prior to 13 September, 1927, are given in the subjoined statement together with the averages of all determinations made on and subsequent to this date. The lower line in each case is the average of the later determinations.

The changes in the west clover plot are uncertain, otherwise the results are decidedly downward. This will also be observed to be the case with the carbon dioxid in the soil atmosphere.

TABLE 36.—Averages of Potassium Determinations Made on 23 September, 1927, Compared With Those Made After This Date.

	WEST PLOT						EAST PLOT					
	0-6 In.		19-24 In.		31-36 In.		0-6 In.		19-24 In.		31-36 In.	
	S	N	S	N	S	N	S	N	S	N	S	N
	28.5	27.4	15.4	22.7	17.2	17.2	23.2	22.6	13.1	11.7	14.4	14.8
Fallow	19.6	18.2	12.8	14.9	14.2	13.8	16.3	16.5	9.0	7.6	9.8	9.4
	44.6	38.8	31.1	23.0	18.9	17.0	17.4	23.7	13.4	41.0	13.1	33.5
Clover	44.2	38.6	34.8	24.8	12.7	11.8	12.1	16.6	15.1	35.9	10.2	21.6
	25.5	39.0	27.3	73.3	20.0	60.0	54.6	39.9	35.6	30.8	18.5	16.1
Alfalfa	17.2	29.0	20.0	60.8	16.7	45.7	41.6	28.5	36.5	21.9	18.3	14.4

GREATEST CHANGE TAKES PLACE NEAR THE SURFACE

The series of samples previously given were not taken to a greater depth than 36 inches. While changes take place to this and greater depths, the greatest changes are much nearer the surface. The exception to this statement is in the case of our west alfalfa plot which was unlike the other plots; it seemed to be anomalous. The rule is that the top 6 inches or even a less depth form the area of greatest change. To what extent greater depths are affected by the downward movement of salts, even of potassium, is an open question. With the exception of the one series the statement that the top 6 inches include the area of greatest change holds good but some changes take place at considerable depths.

In our west fallow there is very little difference in the potassium present in the second 6 inches of the third foot in the south and north halves. There is one date, 3 June, when 37 p.p.m. were found at this depth in each half. With this exception, 24 p.p.m. was the maximum. The average soluble potassium at this depth in the west clover plot was 18.9 p.p.m. for the south half, and 17.0 p.p.m. for the north half or 18.0 p.p.m. for the plot. On 10 October, 1927, these two plots were sampled to a depth of 11 feet in sections of 1 foot each. The potassium and nitric nitrogen were determined in these samples and are given to show the distribution of these constituents. There are added to these the results obtained on composite samples from the two alfalfa plots in 6-inch sections to a depth of 6 feet. These samples were taken 13 October, 1926, when the alfalfa was standing. These samples had been air-dried and preserved for a year, which probably increased the soluble potassium slightly but not materially.

TABLE 37.—The Distribution of Soluble Potassium and Nitric Nitrogen at Different Depths, 27 October, 1927.

ALFALFA				CLOVER		FALLOW	
	Potassium p. p. m.	Nitric Nitrogen p. p. m.		Potassium p. p. m.	Nitric Nitrogen p. p. m.	Potassium p. p. m.	Nitric Nitrogen p. p. m.
First 6 inches	47.9	6	Fourth foot	....	....	9.1	6
Second 6 inches	51.5	2	Fifth foot	8.1	2	7.4	6
Third 6 inches	42.6	2	Sixth foot	6.2	1	8.6	6
Fourth 6 inches	23.9	2	Seventh foot	7.5	1	8.7	6
Fifth 6 inches	11.2	1	Eighth foot	7.7	4	12.0	6
Sixth 6 inches	10.4	1	Ninth foot	27.0	13	15.2	6
Seventh 6 inches	8.8	1	Tenth foot	16.0	18	13.9	5
Eighth 6 inches	10.4	1	Eleventh foot	17.3	10	13.1	10
Ninth 6 inches	15.9	1					
Tenth 6 inches	14.3	1					
Eleventh 6 inches	17.6	1					
Twelfth 6 inches	18.3	2					

DEVELOPMENT OF NITRIC NITROGEN AFTER PLOWING

In earlier paragraphs we have given the nitric nitrogen in the alfalfa, clover and fallow plots for 1926. These series of

TABLE 38.—Development of Nitric Nitrogen in Cropped and Fallow Land After Plowing, in Parts per Million.

1927	WEST PLOT						1927	EAST PLOT					
Depth	0-6 In.		19-24 In.		31-36 In.		Depth	0-6 In.		19-24 In.		31-36 In.	
Date	S	N	S	N	S	N	Date	S	N	S	N	S	N
							ALFALFA						
25 Sept.	5	8	2	2	1	1	28 Sept.	10	14	1	1	1	1
3 Oct.	6	14	2	2	2	1	8 Oct.	10	14	3	3	2	1
14 Oct.	14	10	1	5	1	1	20 Oct.	14	26	6	5	3	2
25 Oct.	14	14	2	5	2	2	28 Oct.	14	11	4	3	1	2
1 Nov.	14	14	3	4	2	2	4 Nov.	14	51	3	5	2	3
8 Nov.	18	16	3	9	2	3	12 Nov.	29	22	5	3	2	3
15 Nov.	14	19	3	6	2	5	18 Nov.	77	32	8	3	3	2
22 Nov.	27	29	3	3	2	2	28 Nov.	19	27	3	3	2	1
							FALLOW						
25 Sept.	24	20	8	8	4	3	28 Sept.	35	19	14	10	6	7
3 Oct.	14	14	12	13	10	11	8 Oct.	6	16	19	14	6	9
14 Oct.	17	18	18	17	10	10	20 Oct.	14	11	14	10	14	6
25 Oct.	18	19	14	15	12	11	28 Oct.	16	16	14	11	8	7
1 Nov.	19	13	10	19	9	10	4 Nov.	16	14	14	14	7	8
8 Nov.	26	19	21	11	12	6	12 Nov.	30	21	13	14	8	10
15 Nov.	29	19	18	18	14	14	18 Nov.	30	19	13	13	6	9
22 Nov.	29	18	24	14	12	6	28 Nov.	19	14	18	14	11	14
							CLOVER						
25 Sept.	10	18	3	3	2	1	28 Sept.	12	6	1	2	1	1
3 Oct.	13	11	3	3	2	3	8 Oct.	10	6	3	3	2	1
14 Oct.	14	16	3	3	1	2	20 Oct.	12	14	3	3	1	2
25 Oct.	14	17	3	3	2	2	28 Oct.	14	11	2	6	6	1
1 Nov.	19	19	3	3	2	2	4 Nov.	19	18	3	3	2	2
8 Nov.	24	27	3	3	2	0	12 Nov.	26	22	3	3	2	2
15 Nov.	27	35	5	3	2	2	18 Nov.	18	22	5	3	6	6
22 Nov.	35	22	5	3	2	2	28 Nov.	13	22	2	2	1	2

samples were not extended into 1927 but on 23 September and subsequently till the end of the season, the nitric nitrogen was determined in the aqueous extract prepared for the determination of potassium by the phenoldisulfonic-acid method as given in Bulletin 31 of the Bureau of Soils, U. S. Department of Agriculture. This was done to ascertain how quickly and to what extent nitrification set in after breaking up the clover and alfalfa plots. The fallow was included for this is, in fact, our best criterion whereby to judge the effects of the clover and alfalfa, for here we have added no organic matter and any increase will be due alone to the changed biological conditions. In the clover and alfalfa an increase might be due, either mainly or wholly, to the food supply added. We expected to find a very decided increase in the nitric nitrogen in the clover and alfalfa ground because of improved conditions and because of the addition of nitrogenous matter in the crop plowed under. How soon and to what extent this increase manifested itself is shown in Table 38. The date of plowing was 13 September.

RATE OF NITRIFICATION AFTER PLOWING

The table presents the rate of nitrification as affected by the plowing under of the clover and alfalfa crops and the plowing of the fallow. We have two composites of the soil for each of our six divisions of land, a total of 288 samples collected on 16 dates covering a period of 60 days. The land had been in the respective crops for a little over 2 years from the spring of 1925 till the fall of 1927. We had removed seven cuttings of clover and alfalfa and plowed under the eighth crop. The fallow had lain the same time and received no cultivation other than hoeing up the weeds from time to time.

The nitric nitrogen in the first foot of the fallow land and also of the alfalfa plots taken in 6-inch sections in 1926 is given in Table 39 in p.p.m. We doubt whether the conditions are really comparable but we give the results to show how they compare.

TABLE 39.—Nitric Nitrogen in the First and Second 6 Inches of Fallow and Alfalfa Plots, in Parts per Million, in 1926.

Date	Fallow		Alfalfa	
	0-6 In.	7-12 In.	0-6 In.	7-12 In.
21 May	7.0	9.0	2.0	1.0
19 June	11.0	10.0	6.0	4.0
27 June	12.0	8.0	8.0	5.0
26 July	11.0	7.0	7.0	3.0
27 August	12.0	8.0	9.0	3.0
25 September	14.0	6.0	7.0	3.0
14 October	12.0	3.0	6.0	2.0
10 November	15.0	10.0	4.0	3.0

The alfalfa and clover land had received a very liberal green manuring and showed an increase in the nitric nitrogen present in the top 6 inches of the soil but it was not in excess of the amount present in the fallow to the same depth except in two samples and one of these is unusually high, 77 p.p.m., probably accidental. The nitric nitrogen in the top 6 inches of the clover and alfalfa land increased several times in the 60 days from 23 September to 22 November, 1927, but it was low at the beginning and it did not exceed the amount in the fallow. There was no increase in the clover and alfalfa land below the 6-inch samples but there was some increase in the fallow, and the fallow was high throughout the mass. While the clover and alfalfa carried only three or four parts per million, except in the top 6 inches, the fallow carried around 14 p.p.m. It may be surmised that the decaying crop filled the soil with carbonic acid which may have hindered nitrification We have thought that this was the case, but we have no proof of this at all. The comparatively sudden fall in the amount of soluble potassium suggests a fall in the carbon dioxid and this is actually the case.

THE BENEFITS OF AN ALFALFA ROTATION ARE NOT DOUBTFUL

The reader must not be tempted to doubt the value of alfalfa in a rotation in our farm practice. The only doubt is in regard to the explanation for these benefits that we have heretofore offered, i. e., that it is due to the addition of available nitrogen. It has been shown that the addition of nitrogen in a more stable form is really very small as the result of a 2-year rotation. The amount is equal to a dressing of from 2 to 4 tons of good stable manure per acre in the 2 years. Of available nitrogen in the form of nitric nitrogen it adds none; on the contrary, it exhausts the soil almost as completely as a crop of wheat under which we have found less than one part per million of this form of nitrogen. The last table given shows that there is scarcely more than this under alfalfa except at the surface of the ground. The aggregate sodium nitrate corresponding to the nitric nitrogen found in 48 samples taken at three different depths, one-third of them from the surface, is under alfalfa, less than one-half as much as we find in the fallow land for the first 60 days after the crop of alfalfa was plowed under.

On the other hand we have seen that the potassium or the corresponding potash in the alfalfa ground shows an increase of 100 p.p.m. for the top 2 feet of soil over the fallow, a total of 800 pounds in two seasons; besides, we removed the crop that carried at least 400 pounds more, making 1200 pounds of potash (K_2O) involved in the 2-year rotation.

We have tacitly assumed that because the alfalfa obtains a part of its nitrogen from the air through the good offices of the root bacillus, and because we have more nitrogen in the crop and soil together at the end than we had in the soil at the beginning of the season, we have therefore added nitrogen to the soil. The debris of the crop that is left on the ground represents the only nitrogen added or even returned to the ground except as stubble.

With the potash it is an entirely different question. The soil that we have to deal with contains a large potential supply of this which is made available by the action of the carbon dioxid excreted by the growing crop in far greater quantities than are necessary to meet the demands of the crop. This excess is represented by the 800 pounds of increase in the top 2 feet of the alfalfa land over the fallow in 2 years.

The fallow land is taken as representing the total activity of the soil population. Its activities were probably modified by the crops; the indications are that they depressed it. The crops were capable of furnishing all of the carbon dioxid found in the soil; the respiration experiments with clover and alfalfa roots and our field observations show this.

Plowing the fallow land was followed by a decrease in the soluble potassium, also in the carbon dioxid; like results were observed in the cropped land, which is surprising as we plowed under a heavy growth of clover and alfalfa.

After plowing, the nitric nitrogen began to increase in the top 6 inches of the cropped and throughout the fallow land to a depth of 3 feet. This was not due to a downward distribution of surface nitrates for there was not rain enough to bring this about and it did not occur in the cropped land.

OBJECTS SET FORTH IN PART I

We divided Part I of this work into two sections; the first was devoted to showing that the amount of carbon dioxide maintained in the soil by such crops as clover and the grasses is sufficient to justify a further study of the amounts set free by wheat and alfalfa and a repetition of the work done on clover in corroboration of the earlier results. The second section was devoted to giving results obtained by experiments to demonstrate how effective this carbon dioxid, aided by water, may be in acting on the mineral constituents of the soil and whether it will work with or against the solvent action of the salts formed upon the soil particles themselves.

SOIL AGGREGATES PROBABLY NOT ACTED ON

It seemed probable that the soil aggregates were scarcely or not at all acted on in the sense that they suffered radical changes in their composition as they had probably already assumed a definite form under the soil conditions. We have in mind that these aggregates are the products of all the changes going on in the soil and have reached a comparatively stable condition for the soil in question. These aggregates contain components that they readily give up to the plants through the soil solutions whereby they become poorer. When these are exhausted, the soil is worn out. So far as this is the case it is equivalent to the statement that the soil solutions are in equilibrium with the aggregates. This seems a simple, convenient and direct explanation, but when these aggregates have given up to the plants the elements that they need it does not follow that they cannot be replaced directly from the mineral particles forming the basis of the soil. We have shown by the action of carbon dioxid on felspar that this is actually the case.

IMPORTANCE OF POTASH

We believe that the claim made that potassium is more closely related to the volume of the crop produced than either of the other two elements usually considered in this connection, is correct and so far as the soil aggregates are concerned, the variation of this element, if we can determine this with sufficient accuracy, and we can, will aid very materially in judging of the changes that take place in the soil.

In the second view, i. e., that the potassium is withdrawn from the aggregate but may be replaced by potassium derived from the mineral particles, which determine the supply, the equilibrium is ultimately with them. The second section of Part I established in another form, what our natural mountain waters everywhere show, i. e., that water and carbon dioxid break up the felspar with the elimination of potash in the form of carbonate to a greater degree than any other component, often almost as freely as all others taken together. The data given in this connection are conclusive regarding the adequacy of this agent to bring about the soil conditions that we have to deal with, and to produce the changes that we have to consider rapidly enough to answer all of our questions in regard to the potassium.

POTASSIUM AND NITROGEN PRESENT DIFFERENT PROBLEMS

The potassium and nitrogen present two very different questions. The carbon dioxid in conjunction with water is strongly enough acid to eliminate potassium from the rock par-

ticles, the sole source of a new supply, but there is no such supply of nitrogen. The medium through which an increase in this is brought about is through the direct or indirect agency of living organisms. The direct agency of these organisms in producing the nitrates found in our soils is evident and it operates on an important scale. While the carbon dioxid is the chief agent in preparing the potassium in the soil for the use of plants, its effect upon the production of nitrates in the soil is to depress it.

RELATION OF ALFALFA TO NITRATES NOT CLEAR

The relation of our alfalfa crop to the nitrates in the soil is perhaps not very clear but there is no question about the small amounts of nitrates present in alfalfa soils. They are always very low and the carbon dioxid is always very high as the succeeding portion of our work will show. We believe that the low nitrates are due to their depression rather than to their exhaustion from the soil by the growing plant. It would be very interesting to know how much of its nitrogen alfalfa can and does obtain from the atmosphere. The fact that it gets, or may get some of its nitrogen from this source leaves us in doubt about the cause for the small amounts of nitrates found in soils occupied by this as a growing crop.

This uncertainty does not obtain in the case of grains. We have seen that at the time of harvest the nitrates under wheat, and the same is true of oats, are equal to only a few parts per million, from none to two or three parts. After harvest, the gain is, at first, very slow and though the rate increases it requires several months for the land to regain as much as it had before the crop was planted. In this case the supply of the nitrates was not only exhausted but there was a tendency toward suppressing the process of formation. We believe that the subsequent presentation of the amount of carbon dioxid given off by the growing wheat crop will fully account for this, and both clover and alfalfa act even more energetically in the same manner because they do continuously, from early spring till in the winter, what the wheat does for the first few weeks of its active growth, namely, they flood the soil with carbon dioxid and continue to do so on a moderate scale through the winter till the succeeding spring when the same cycle is repeated.

SOME DIFFERENCES BETWEEN WHEAT AND ALFALFA

In regard to depressing the formation of nitrates the crops are alike in their action except that the clover and alfalfa are

active throughout their lives, which in the case of the alfalfa may be for many years while the wheat is very intense for a few days. This is the way the wheat acts and we believe that it is the same in the other cases. Their reaction upon the soil in regard to potassium differs in that the question is simply a chemical reaction and not one developing upon living organisms which may be partially or wholly destroyed. Some of the beneficial organisms may re-establish themselves and possibly show greater vigor than before they were depressed. In this matter the course of affairs may vary in all sorts of measures depending upon the competition offered by other organisms, the temperature, moisture, sunshine, vigor and degree of maturity of the growing crops.

The wheat plant as it approaches maturity reaches a maximum intensity in its production of carbon dioxid which abates rapidly as maturity advances. This is the case too with the clover and alfalfa but these crops provide for the production of new plants and we change the course of affairs by cutting the old growth, by irrigating and forcing a new growth, when they again fill the soil with carbon dioxide. At the end of our work it appears that we might have made an interesting variation in our experiments by allowing a part of our crops, the clover for instance, to ripen just as the wheat ripened and recorded the results. We did not do this but we observed that when the clover came into bloom and stood a little longer there was a falling off in the carbon dioxid. This was very marked. The same occurred in the case of the alfalfa. This point is probably a fixed one for each plant and is so sensitive that slight differences in the time of irrigation express themselves in the time of this falling off in the carbon dioxid, due to its influence upon the development and maturation of the plant.

MATURING AND CUTTING OF ALFALFA AN IMPORTANT FEATURE

In view of this deportment of the plants, the cutting of clover and alfalfa is an important feature in the rotation. Our cutting and irrigating of the crops is in imitation of farm practice which is governed by the quality of hay desired as well as the quantity gathered. The practice is comparatively uniform in this section, three cuttings with always two and sometimes three irrigations. The plants reach a maximum of growth and these tend to ripen whatever the conditions may be. New plants may grow but the old ones go down. The wheat has only one period of growth and when maturation sets in, the process continues till the end and no new plant takes its place; this is its end.

It gives off carbon dioxid abundantly till this maturing period arrives when the carbon dioxid begins to fall and continues to fall till the plant is fully ripe. In our practice we cut alfalfa at the beginning of this period, just at the time this natural falling off in the carbon dioxid begins. We do not know how far it would go if no second growth should appear; it would probably not become zero so long as the crowns and roots retain their vitality. The cutting in this case does not induce the falling off in the development of the carbon dioxid, but by hastening a second growth, brings about a further production of it. If we cut the crop before the period of maturation sets in, we stop the activities of the plant before provision for the second growth has been completed, and we change the order of events in an important manner. In this case the cutting actually causes the falling off in the carbon dioxid by removing the aerial portion of the plant and this lengthens the period between the cutting and the production of the second growth. In this case there is more time given for the carbon dioxid to fall. In our preliminary series it fell below the amount present in the fallow ground on the same date. We tentatively interpreted this as showing that the activity of the soil population was strongly depressed, at least, it was not as efficient in the ground planted to clover as in the fallow. The difference in the results obtained in our two series is wholly due to the fact that in the preliminary series we cut the crop several days before it had reached the point where vegetative functions cease and ripening begins; this point is very definitely indicated by a falling off in the carbon dioxid in the soil air.

THE EFFECTS OF THE NEW GROWTH

This change in the clover and alfalfa is accompanied by a provision for another vegetative period and new shoots begin to be thrown out at the crown of the plant. The ripening may go on but the plant provides for a new growth. This point is observed by the ranchman in judging when his crop should be cut and gotten out of the way lest he suffer both inconvenience and loss. There is an overlap in processes, the dying of the old crop and the growing of the new crop. When we cut our clover in a state of immaturity we anticipated the second process by enough to avoid the overlap that takes place when we cut the crop just after the point of maturity has passed. It is probable that our field practice of cutting alfalfa just after maturity interferes very little with the natural course of development.

In our preliminary series the method of irrigating was garden and not field practice. While this did not give us the

order of things as they occur in field practice, it is not to be regretted, for it probably gave us a clearer picture of the development of the plants than we get when it is involved by questions of the effects of irrigation. We have observed that these crops are exceedingly sensitive to the amount of moisture at their disposal. This period of maturation is a critical period in the history of the plant; it is finishing one of its phases and is preparing to renew its growth. The ranchman realizes this when an inopportune rainy season intervenes at this period. Then the hay crop and the second growth interfere with one another.

Our field practice is to let the crop stand till the ripening period has set in, when it is cut and irrigated very shortly after the crop has been removed. During this period the carbon dioxid is low but begins to rise immediately with the growth of the new crop. Alfalfa, which is our cultivated hay crop, is extremely sensitive to water, rain or irrigating water, during its whole life. A comparatively light rain will cause it to grow more rapidly and every change in its rate of growth is accompanied by a change in the amount of carbon dioxid evolved.

We have not mentioned the effects of temperature but this too is important. Alfalfa during its growing period responds promptly to any change. A few days at 60° F. after a period of 70° F. will be accompanied by a depression of the carbon dioxid.

I do not know whether or not wheat during its growing period is as sensitive to these factors as the clover and alfalfa. The plants are different—the wheat provides for the perfecting of its seed. This is its sole object and it makes no provision for its continuance by any other means. The parent plant fulfills this purpose and dies. This is the end of its activities; it cannot repeat the process as the clover and alfalfa can. During its life time the wheat tends to produce the same results as the clover and alfalfa. Its period is short and it is probably not able to supply its own needs but requires that these be prepared for it. It showed a reduction of the soluble potassium below the amount found in the check plot. We do not know how much this signifies for we do not know that the amount of soluble potassium remained stationary in the fallow plot. If it changed it was probably upward as there was a moderate and constant supply of carbon dioxid and no plants except the soil population itself to use it up or to render it insoluble.

Any factor that promotes the growth of the plant will increase the carbon dioxid and any one that checks the growth will cause a downward variation in it. When maturity is reached

the carbon dioxid falls and unless new plants are produced it will continue downward as in the case of the wheat.

This harmonizes with the data given in Bulletin 319 with the observations of our field practices. The former observations were made on growing, immature plants, the latter on maturing ones. The change from an increasing to a decreasing plant is marked by a decreasing amount of carbon dioxid in the soil atmosphere. If we make an artificial change by cutting the plants before the period of ripening has begun, we bring about a fall in the carbon dioxid before the plant has made its preparation for the new growth. This allows for a period of very low carbon dioxid during which, according to our preliminary observations, it may fall as low under clover as in the fallow land. In this case the fall in the amount of the carbon dioxid was due to the cutting of the plants and not to a natural maturing process as takes place in our general field practice.

The water supply immediately after the cutting will greatly influence the promptness and rapidity of accumulation of the carbon dioxid again. We cannot lay too much stress on the effects of the water supply. If this is lacking, as in the case of uncultivated and unirrigated alfalfa plants, they go to seed and subsequent growth is far less vigorous or absent. The plants do not die but under these conditions their season's energies are represented by the one crop of seed.

In Part I, second section, we give the effects of carbon dioxid on both the felspar that is abundant in the soil experimented with, and on the soil itself. The efficiency of carbon dioxid in bringing about the liberation of potash from these sources was demonstrated; besides, the mountain waters demonstrate the same thing. It remains to be shown that clover and alfalfa produce enough of this agent to bring about the changes claimed, i. e., to set free from the felspar and soil, quantities of potash, larger than they use in their own growth by 100 pounds per million pounds of soil in 2 years. This is given for the top 2 feet of soil but the carbon dioxid is very abundant at greater depths under alfalfa.

TABLE 40.—Mean Daily Temperatures From March, 1926, to September, 1927, Inclusive, Furnished by Mr. R. Trimble

Date	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	36.9	29.5	56.4	63.6	71.6	71.7	66.5	52.3	37.2	38.6	38.3	31.8	19.3	43.6	58.5	58.1	61.0	61.9	66.0
2	39.3	24.3	58.1	68.3	68.1	72.2	65.1	53.0	36.9	42.9	39.0	38.3	25.1	50.1	62.5	55.2	68.1	56.2	65.4
3	40.6	30.5	56.0	57.3	67.1	73.7	60.4	54.8	30.9	46.4	45.0	38.5	35.7	51.6	47.4	57.8	68.8	64.0	65.6
4	39.4	45.4	59.1	62.4	65.1	70.8	58.0	49.5	35.1	37.6	43.3	40.0	34.6	49.6	55.4	52.6	71.6	63.6	66.8
5	42.4	31.6	58.3	65.1	67.2	72.6	67.5	47.3	44.3	36.9	47.4	37.6	36.7	46.5	50.4	53.4	69.0	68.4	67.3
6	26.1	39.2	51.2	66.2	63.3	66.4	61.0	53.0	46.1	34.6	36.4	31.1	36.4	50.7	57.2	61.6	69.0	69.4	63.5
7	31.3	35.1	50.7	67.0	70.4	68.0	64.8	55.7	44.1	34.5	37.9	31.5	34.9	52.5	64.2	64.1	70.4	67.4	66.5
8	36.3	43.2	46.8	64.8	65.4	68.9	60.1	58.3	36.9	26.6	34.1	15.1	41.1	50.1	44.4	66.3	70.6	57.8	66.2
9	39.9	34.8	49.0	65.7	62.5	69.8	61.2	52.5	34.9	15.8	27.8	5.9	39.6	51.2	42.6	71.2	71.6	63.4	70.1
10	37.0	45.2	49.6	65.9	61.6	67.3	62.5	59.5	39.6	20.5	25.0	16.4	27.1	44.1	44.6	65.7	71.2	64.3	69.0
11	40.9	43.5	45.0	66.1	65.1	71.3	62.0	59.1	43.9	34.9	33.8	24.6	29.0	35.6	50.6	64.7	68.9	67.8	68.7
12	41.9	46.2	47.0	64.6	70.4	67.0	54.6	47.2	48.9	13.8	19.8	25.0	33.0	33.2	56.6	47.6	69.5	65.2	68.4
13	37.3	46.5	47.5	59.9	70.0	64.9	60.8	53.0	40.4	—6.0	14.6	27.1	39.7	31.5	59.3	46.2	67.0	64.2	69.4
14	32.6	45.1	49.0	59.3	67.9	69.1	62.9	50.4	41.4	—8.2	16.3	27.5	43.2	27.8	54.1	51.0	63.0	63.2	63.7
15	28.4	51.8	55.5	66.0	70.2	66.3	65.7	56.9	41.5	0.2	29.5	37.3	40.1	28.6	56.4	57.9	67.4	66.4	64.9
16	43.3	54.6	57.5	57.3	75.1	62.8	62.2	59.0	38.8	22.2	43.8	39.6	31.1	36.8	66.0	55.0	64.6	60.2	65.0
17	48.6	58.9	53.8	58.5	69.6	64.6	61.0	68.4	33.8	27.0	24.4	24.5	29.1	44.6	65.6	62.6	69.3	61.9	67.8
18	47.7	51.7	54.4	61.2	70.3	66.4	57.5	51.9	31.0	25.3	28.8	23.7	30.2	46.3	58.4	67.7	73.2	59.6	57.3
19	43.6	51.6	54.9	64.9	73.7	67.6	56.4	49.6	27.1	30.1	30.9	41.5	13.7	34.4	57.2	62.6	71.6	60.4	55.3
20	43.2	54.9	61.1	63.6	70.4	64.3	62.9	46.2	23.8	26.1	27.8	41.0	8.0	35.4	58.0	65.0	67.6	65.8	49.2
21	39.1	50.4	61.4	53.6	60.8	67.4	69.4	51.7	29.5	19.3	4.1	48.2	18.7	33.1	62.0	56.8	68.8	64.5	52.1
22	45.2	50.7	61.0	60.5	65.0	67.2	63.4	42.3	43.0	21.6	15.5	38.6	31.2	40.4	61.4	54.4	65.5	63.6	52.6
23	50.1	46.0	64.3	60.4	69.2	66.4	57.3	33.2	44.8	20.1	22.7	38.9	30.6	48.0	53.4	68.3	68.6	60.0	55.2
24	38.7	43.1	64.5	60.6	64.6	68.8	36.2	47.5	45.9	6.1	28.0	37.4	39.3	45.2	61.0	73.4	65.8	65.1	54.7
25	29.7	49.6	62.9	60.2	66.7	68.3	36.9	59.8	44.9	12.6	28.8	30.8	36.5	54.6	58.0	68.6	65.2	67.2	39.1
26	26.5	52.8	61.4	67.9	65.3	71.9	35.5	52.1	42.9	14.5	21.7	35.8	40.5	60.6	61.0	73.8	65.0	65.9	31.5
27	26.9	52.6	57.1	70.8	68.3	71.6	48.1	56.3	42.4	11.2	34.8	27.4	36.7	61.5	59.7	73.0	69.4	62.8	44.4
28	20.7	51.5	57.7	75.5	71.7	70.2	52.8	39.6	39.8	19.1	42.9	17.1	46.4	55.8	62.4	71.3	66.0	67.2	43.6
29	12.7	57.1	59.7	72.6	63.1	66.1	56.6	30.2	37.8	21.8	33.5		43.9	53.7	54.6	66.7	63.0	68.2	52.6
30	12.6	58.5	59.6	70.7	64.1	70.4	56.3	23.7	48.1	30.8	32.7			58.2	50.5	64.6	61.5	66.6	43.9
31	17.8		57.7		68.1	68.1		33.5		34.8	27.3				51.5		63.4	65.0	

TABLE 41.—Soil Temperatures.

Date	ALFALFA			FALLOW			WHEAT		
1926	12 In.	18 In.	48 In.	12 In.	18 In.	48 In.	12 In.	18 In.	48 In.
24 May	54.5	53	35	66	65	57	62.5	61	52
27 May	55	53	35	64.5	63	58	62	61	51
1 June	56.5	54	37	61.5	61	59	61	60	broken
4 June	57	56	38	68	66	57.5	63	62	
9 June	58	57	39	70.5	68.5	63.0	65	64	
14 June	58.5	58	40	67	67	63	63.5	63	
17 June	58.5	58	40	65	65	63	63	63	
21 June	57.5	58	40	67.5	67	63	62.5	63	
24 June	60.5	59.5	40.5	70	68	64	63.5	63	
26 June	62	61	40.5	69	68	65	63.5	63	
29 June	67	66	43	74.5	73	66	66.5	66	
2 July	67.5	66.5	44	74.5	73.5	66.5	67.5	66.5	
6 July	66.5	66	46	73.5	73	67	67	66	
10 July	63	63	46	67	68	67	65	65	
13 July	64	63	46	71.5	70	67.5	65.5	65	
16 July	64	64	46	72	71	68	66.5	66	
20 July	65	64	46	76	74.5	70	68.5	68	
23 July	63.5	63	46	73	72	69	67	66	
28 July	63.5	63	46	75	73	69	68.5	66.5	
3 Aug.	64	63	46	77.5	76	70	71	69	
7 Aug.	63.5	63	46	72.5	76	70	68	68	
11 Aug.	64.5	64	47	73.5	72	71	68.5	68	
14 Aug.	67.5	66	48	74.5	73	71	70	69	
19 Aug.	66.5	66	48.5	73	72	71	69	69	
24 Aug.	67	66	48	broken	73.5	71	72	71.5	
27 Aug.	60.5	66	49		76	72	74.5	74	
31 Aug.	66	65.5	49		76	73	75	74	
8 Sept.	58	58	45.5		66	68	66	65	
24 Sept.	55.5	56.5	43		65	66.5	62	64	
1 Oct.	56	56.5	43		61	64	58	60	
7 Oct.	55.5	55	43		58	63	57.5	57	
14 Oct.	54.5	55	42		59	62.5	57.5	58	
19 Oct.	54.5	55	42		59	62	59	58.5	
27 Oct.	55	50	40		54	60	54	54	
5 Nov.	41	43	35		43	55	42	43	
12 Nov.	41.5	41.5	33		43	51.5	42.5	43	
18 Nov.	37.5	38	31		39	50	38	39	
24 Nov.	36.5	37	29		38	49	38	38	
3 Dec.	37.5	37	28		39.5	46.5	38	38.5	
11 Dec.	36.5	37	27		37	46	37	37	
20 Dec.	33.5	Too low	28		Too low	43	33	Too low	
27 Dec.	31		Too low			42	29		

Table 41.—Soil Temperatures.

Date	ALFALFA			FALLOW			WHEAT		
1926	12 In.	18 In.	48 In.	12 In.	18 In.	48 In.	12 In.	18 In.	48 In.
1927									
5 Jan.	32					40	32		
12 Jan.	31.5					40	31.5		
20 Jan.	30					40	30		
28 Jan.	30					39	30		
4 Feb.	31					40	30		
11 Feb.	31					39	30		
18 Feb.	31					38.5	31.5		
5 Mar.	32	Two low	Too low	Broken	Too low	38	35	34	broken
14 Mar.	35.5	35			35	40	36	35	
23 Mar.	34	34			33	39	34	33	
31 Mar.	41.5	40			40.5	42	42	41	
8 Apr.	48	46.5			49	46	49	48	
15 Apr.	40	40			40	46	39	40	
23 Apr.	43.5	43			43	45	44	42	
2 May	52	50			56	51	58	55	
10 May	48.5	48.5			51	53	50	51	
16 May	52.5	51.0			59	55	59.5	57	
22 May	54.5	53.5			65	59	63	62	
31 May	54	53.5			63	59	60	59	
6 June	54	54			60	60	59	58	
13 June	55	54			61	60	59	60	
20 June	57	56			64	61	63.5	62.5	
27 June	60	59			71	64	70	69	
5 July	68.5	68			75	66	75	72	
11 July	68	68			73.5	69	70	70	
18 July	66.5	66			74	69	70	70	
25 July	65.5	65			74	69.5	69.5	69.5	
1 Aug.	66	65			70	68	66.5	66	
8 Aug.	66	66			69	68	64.5	64.5	
15 Aug.	66	66			68	68	64.5	64.5	
22 Aug.	64	64			71	68	63.5	63	
29 Aug.	64	64			72	69	64.5	64	
12 Sept.	63.5	63			71	70	64.5	64	

TABLE 42—Rainfall. Furnished by R. Trimble.

	1925				1926												1927								
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1								.14							.08									.01	
2					.07			.10					.01											.12	
3			.05		.09							.05	.26	.06	.25							.32		.03	
4	.06		.03									.04	.64						.04			.27		.52	.14
5		.33					.02				.23		.05						.02		.01	.47			
6		.41		.03				.02	.18			.37				.03								.07	.01
7		.02						.06	.12	.03	.03	.11				.02									
8		.15						.47	.19		.04	.06				.42		.11			.69			.05	
9		.01						.53		.02		.13				.06		.01					.03		
10							.16					.02							.32	.10		.05			
11		.40			.01		.01		.21										.24	1.15			.13		
12		.20							.03			.06				.11	.02			.46	.10	.19	.14	.37	
13	1.70	.19	.31	1.23			.03	.15	.06	1.06		.02				.01				.04		.10	.25	.08	
14	.14	.20	.24	.13			.02		.02	.29	.10		.04							.59		.13	.12		
15									.01		.02									.13		.01			
16		.52							.01	.07					.02				.01			.05		.03	
17		.15				.26				.05															.03
18		.22				.02			.03										.02			.02			
19							.14												.31			.02			
20		.01			.05			.01			.21								.03	.01				.35	
21							.79	1.17							.01		.02					.14	.12		
22	.06				.01								.03						.23					.22	.06
23		.07						.04						.07		.17				.14				.12	
24		.15			.02					.05						.01				.07			.14		.17
25		.05					.03															.32			.25
26			.18				.01		.17		.02											.01	.10		.12
27			.08	.11			.05	.30	.50		.02							.13	.01						
28		.01					.13		.01		.06			.03				.12				.05	.30	.01	.01
29		.17					.11		.09		.20			.98								.02	.80		
30									.13	.01				.01					.04				.05		.31
31							.04												.60		.11		.01	.12	
Total	1.96	3.26	0.89	1.50	0.25	0.28	1.54	2.99	1.76	1.58	0.93	0.86	1.03	1.15	0.36	0.83	0.04	0.40	1.87	2.69	0.91	2.17	2.19	2.10	1.10

TABLE 43.—Parts Carbon Dioxid in 10,000 Parts of Soil Air in Experimental Plot from March, 1926, till September, 1927, Inclusive. Corrected to 0° and 760 mm.

Crop	Depth Inches	No.	1926 3/1	3/8	3/15	3/22	3/31	4/6	4/10	4/19
					Dates of collection of samples					
	6	1	33.45	32.51	25.78	27.64	30.72	47.81	46.80	41.76
Alfalfa	18	2	52.50	50.26	53.27	54.50	53.90	56.04	79.57	113.26
	30	3	48.55	49.45	37.42	40.56	52.57	49.23	65.69	79.17
	6	6	12.44	7.71	9.30	7.62	4.56	9.19	10.37	15.39
Fallow	18	5	21.03	12.35	17.09	12.96	9.13	9.19	20.74	21.55
	30	4	25.68	24.72	26.17	24.83	21.67	21.14	23.81	30.06
	6	8	11.66	10.78	8.49	6.10	....	13.01	16.11	20.27
Wheat	18	7	21.97	15.39	18.55	16.77	14.44	21.40	25.30	22.60
	30	9	22.53	20.04	15.34	23.64	22.94	25.23	26.19	19.48
	6	10	20.94	18.51	13.80	13.72	19.11	25.98	34.19	34.35
Clover	18	11	44.16	43.85	39.75	48.11	35.14	48.00	53.68	77.02
	30	12	57.29	52.79	43.54	54.52	51.95	47.96	56.71	77.68
	6	16	23.99	27.76	15.27	20.46	27.89	32.74	44.51	48.00
Alfalfa	18	17	54.17	55.37	45.80	48.37	55.81	54.73	65.77	94.86
	30	18	55.62	52.88	47.30	55.15	51.60	55.11	65.81	86.87
	6	19	19.31	8.81	7.63	10.03	3.07	9.52	16.80	31.82
Wheat	18	21	22.45	18.10	19.77	20.88	16.11	21.96	31.74	25.20
	30	20	23.98	29.79	25.11	....	23.78	25.17	30.60	35.68
	6	24	11.60	7.62	9.10	6.59	7.68	7.75	10.64	18.15
Fallow	18	23	20.12	13.73	15.18	19.30	16.50	19.39	22.06	22.85
	30	22	23.21	19.08	18.57	19.33	14.57	29.45	22.86	23.25
	6	25	29.30	16.75	22.76	11.58	16.12	30.62	38.10	41.19
Clover	18	26	38.45	37.71	38.59	39.78	38.37	39.51	49.62	68.51
	30	27	39.39	42.62	33.44	39.34	50.63	45.25	48.73	71.94
Air						1.56	3.84	5.37	4.57	6.16

Crop	Depth Inches	No.	1926 4/26	4/29	5/3	5/7	5/12	5/17	5/20	5/24
					Dates of collection of samples					
	6	1	71.20	95.27	68.31	52.08	58.83	66.06	56.37	60.71
Alfalfa	18	2	161.08	165.33	177.63	146.62	155.53	131.67	118.18	112.19
	30	3	116.36	158.74	157.55	148.10	128.72	152.34	131.17	107.59
	6	6	19.87	27.28	18.73	24.78	21.22	23.69	17.10	29.75
Fallow	18	5	25.23	28.71	42.09	36.63	42.37	36.28	35.36	50.29
	30	4	35.15	38.69	33.77	44.29	46.18	41.27	43.36	43.54
	6	8	38.15	49.14	34.74	35.64	30.38	42.41	34.57	24.53
Wheat	18	7	32.49	58.74	53.46	38.72	40.09	49.27	51.30	66.09
	30	9	35.22	51.23	50.08	54.35	45.35	53.14	56.15	59.23
	6	10	66.50	81.85	60.74	47.02	43.01	39.00	41.72	44.97
Clover	18	11	127.57	106.70	116.97	100.96	98.17	103.96	86.87	89.56
	30	12	126.66	102.94	113.92	115.83	110.89	107.71	110.01	93.02
	6	16	90.72	105.57	61.65	69.12	72.94	71.55	61.42	55.63
Alfalfa	18	17	141.90	162.37	181.95	164.12	159.36	141.24	161.78	128.88
	30	18	112.56	118.92	150.24	144.42	164.73	164.39	162.47	141.08
	6	19	32.00	45.14	38.04	38.55	45.35	42.31	28.43	27.46
Wheat	18	21	48.55	46.69	51.21	56.86	60.91	38.90	39.67	60.16
	30	20	44.75	55.56	48.65	59.74	51.47	48.88	57.63	64.37
	6	24	23.61	25.42	17.04	26.32	17.44	23.47	18.57	17.14
Fallow	18	23	43.27	32.62	38.70	40.45	26.41	40.47	45.53	33.10
	30	22	27.85	33.47	33.40	45.03	44.32	39.67	30.64	35.78
	6	25	37.78	39.07	33.65	31.29	26.66	41.53	34.75	30.46
Clover	18	26	80.41	76.29	113.79	97.71	82.49	84.64	....	78.33
	30	27	96.22	111.00	106.49	116.04	103.23	101.51	100.39	107.17
Air			5.77	8.37	6.42	none	6.90	none	7.98	6.84

TABLE 43—Continued

Crop	Depth Inches	No.	1926 5/27	6/1	6/4	6/9	6/14	6/17	6/21	6/24
	6	1	52.62	52.87	65.92	69.06	103.89	106.14	96.83	67.02
Alfalfa	18	2	107.97	154.11	173.94	173.94	172.56	226.55	229.52	218.84
	30	3	114.25	154.53	203.82	213.90	216.98	225.99	294.02	211.08
	6	6	22.78	24.88	27.73	25.22	33.23	44.79	23.00	22.45
Fallow	18	5	43.63	37.48	55.07	61.28	39.76	....	59.30	59.57
	30	4	53.47	39.45	48.55	52.89	64.90	65.82	59.30	66.52
	6	8	35.08	91.14	92.18	60.02	90.50	144.70	71.44	64.19
Wheat	18	7	68.27	32.03	157.02	146.34	136.70	171.25	166.72	140.73
	30	9	70.73	94.93	123.67	152.24	150.02	167.20	190.24	140.73
	6	10	55.41	77.34	62.96	51.25	69.77	97.85	38.98	38.69
Clover	18	11	78.23	92.63	113.48	110.93	113.32	140.48	128.25	114.09
	30	12	109.93	110.19	134.13	141.81	143.16	148.93	158.74	141.47
	6	16	62.23	95.59	100.38	81.46	140.51	158.85	151.52	113.97
Alfalfa	18	17	129.00	56.12	215.35	215.63	....	248.40	264.19	246.37
	30	18	160.46	150.00	172.33	180.50	188.43	215.45	250.87	217.53
	6	19	37.43	91.00	88.46	59.82	96.79	162.63	66.92	46.34
Wheat	18	21	67.90	133.87	145.79	143.87	139.01	166.50	168.12	134.09
	30	20	60.28	93.80	130.12	145.07	154.29	166.50	177.39	191.54
	6	24	18.43	26.25	27.47	23.00	30.67	44.05	24.11	23.25
Fallow	18	23	46.12	30.13	52.64	59.78	41.81	46.40	56.77	61.88
	30	22	38.11	40.97	41.61	63.23	43.66	46.02	59.13	64.13
	6	25	46.85	89.57	47.28	26.03	66.77	75.27	49.00	43.36
Clover	18	26	72.16	110.63	118.19	107.14	99.58	120.22	99.94	104.14
	30	27	98.55	96.37	127.67	131.23	132.10	130.88	135.72	137.04
Air			3.83	3.85	3.07	9.18	none	6.16	1.94	2.33

Crop	Depth Inches	No.	1926 6/26	6/29	7/2	7/6	7/10	7/13	7/16	7/20
	6	1	84.11	97.03	60.94	81.72	73.91	96.91	114.22	99.01
Alfalfa	18	2	215.33	242.48	216.03	200.30	147.97	233.36	238.38	....
	30	3	223.08	223.42	223.66	183.67	192.60	261.14	260.56	263.41
	6	6	20.13	29.97	24.10	36.00	52.56	52.70	52.12	34.61
Fallow	18	5	51.54	61.86	58.94	57.54	53.70	58.85	57.08	60.05
	30	4	59.64	64.93	60.12	74.83	68.03	71.48	65.93	75.74
	6	8	28.97	40.34	30.58	23.73	....	102.62	102.61	44.75
Wheat	18	7	139.56	131.09	112.49	97.66	101.21	142.64	146.09	126.12
	30	9	148.30	147.53	133.07	115.86	131.34	145.98	143.73	147.54
	6	10	37.05	33.79	39.37	47.41	129.70	130.97	....	51.71
Clover	18	11	104.98	108.35	114.64	112.03	110.28	169.10	173.67	162.27
	30	12	135.08	137.16	142.17	138.15	155.69	177.47	189.88	197.55
	6	16	99.96	86.33	77.55	85.15	86.02	144.08	130.88	103.31
Alfalfa	18	17	228.31	246.33	244.33	217.43	218.25	257.49	260.13	261.34
	30	18	239.51	245.64	252.62	246.76	232.89	255.79	266.17	268.39
	6	19	51.69	50.59	30.55	33.35	100.97	131.24	76.88	54.72
Wheat	18	21	119.57	122.52	107.69	78.77	98.93	138.23	135.51	120.26
	30	20	162.77	154.78	149.68	130.32	146.33	146.69	148.27	150.68
	6	24	20.82	21.41	22.97	21.92	53.89	34.51	28.18	35.35
Fallow	18	23	50.15	62.03	59.76	51.40	52.73	55.60	45.00	83.76
	30	22	62.50	70.82	68.74	71.81	75.84	57.51	68.76	92.16
	6	25	36.21	35.17	36.75	51.40	129.77	113.82	77.68	60.63
Clover	18	26	102.85	103.55	105.66	113.52	120.79	172.48	178.21	151.07
	30	27	122.45	134.76	133.97	135.75	128.50	157.08	175.67	167.10
Air				5.35	10.33	3.78	6.17	6.89	3.81	....

TABLE 43—Continued

Crop	Depth Inches	No.	1926 7/23	Dates of collection of samples 7/28	8/3	8/7	8/11	8/14	8/19	8/24
	6	1	70.83	70.89	81.63	92.21	113.22	89.72	58.54	46.57
Alfalfa	18	2	229.34	220.56	196.71	195.77	199.03	191.97	185.80	154.70
	30	3	237.55	214.43	232.70	232.76	211.65	171.26	174.89	168.49
	6	6	35.88	36.85	40.00	38.42	30.74	31.46	21.12	13.18
Fallow	18	5	57.88	61.77	61.54	61.49	61.53	62.93	57.62	58.11
	30	4	74.46	83.44	81.59	84.55	86.19	70.07	72.25	75.93
	6	8	36.16	33.67	lost	22.25	26.07	23.78	21.49	22.79
Wheat	18	7	112.83	96.08	84.62	84.39	67.09	65.23	57.15	58.39
	30	9	137.71	117.51	115.66	99.41	97.32	89.99	78.06	81.92
	6	10	50.84	48.49	42.24	60.61	46.94	47.45	39.56	31.08
Clover	18	11	128.89	131.61	117.95	113.46	117.38	118.69	93.64	91.19
	30	12	187.62	172.98	164.57	157.03	154.27	153.19	129.88	124.90
	6	16	90.14	77.68	....	82.32	97.17	87.71	60.42	46.43
Alfalfa	18	17	251.18	252.58	197.00	209.14	195.15	192.16	184.33	174.61
	30	18	250.42	254.88	257.02	262.29	248.51	218.55	223.21	216.62
	6	19	37.72	38.43	28.02	40.33	48.58	30.85	19.89	21.55
Wheat	18	21	113.85	94.22	84.85	82.47	58.96	60.02	50.40	44.66
	30	20	149.74	125.91	123.62	115.91	101.69	103.14	99.31	88.41
	6	24	32.17	24.84	21.48	36.05	34.63	23.80	20.19	13.74
Fallow	18	23	57.48	58.85	45.29	47.59	46.17	48.77	42.76	48.38
	30	22	78.61	82.67	87.05	76.80	70.44	73.87	72.53	67.02
	6	25	49.81	48.17	26.09	42.16	50.02	49.85	30.66	39.32
Clover	18	26	130.95	119.81	105.58	96.63	106.55	95.83	80.77	82.38
	30	27	157.02	145.69	145.45	128.12	138.42	120.23	112.18	107.47
Air			9.20	8.40	8.42	2.70	6.92	7.65	9.31	15.64

Crop	Depth Inches	No.	1926 8/27	Dates of collection of samples 8/31	9/9	9/18	9/24	10/1	10/7	10/14
	6	1	52.15	65.49	84.26	74.48	56.91	44.26	37.14	26.91
Alfalfa	18	2	151.64	152.03	174.38	151.67	122.05	113.10	94.54	87.66
	30	3	177.19	169.91	187.10	180.89	169.38	123.21	98.14	95.62
	6	6	13.38	25.49	22.96	18.33	20.14	16.91	27.96	23.04
Fallow	18	5	58.85	60.57	50.74	45.55	45.91	43.14	42.66	31.94
	30	4	74.23	77.28	70.11	60.75	66.29	69.25	66.36	66.13
	6	8	32.10	21.96	29.80	28.17	32.48	17.06	12.99	11.51
Wheat	18	7	65.81	64.09	48.93	49.54	41.79	38.44	38.14	28.05
	30	9	78.50	79.08	76.32	70.03	60.88	57.06	51.08	51.35
	6	10	29.05	35.14	64.83	60.10	39.65	30.94	27.82	17.62
Clover	18	11	102.48	109.79	109.96	110.19	104.99	79.83	79.25	63.59
	30	12	131.39	129.17	125.25	130.48	109.70	104.50	92.25	78.81
	6	16	51.12	49.52	81.47	63.89	41.18	39.95	32.35	32.51
Alfalfa	18	17	169.84	171.43	187.03	....	162.78	121.31	115.05	107.07
	30	18	220.72	224.84	229.09	220.81	177.98	174.58	139.73	136.13
	6	19	26.33	26.63	34.86	28.90	19.18	21.51	23.70	19.88
Wheat	18	21	44.27	34.09	37.16	29.10	36.40	36.29	35.79	25.68
	30	20	94.35	83.42	75.54	74.90	72.49	69.16	61.26	50.27
	6	24	15.17	25.00	23.04	21.31	19.10	15.37	16.22	13.02
Fallow	18	23	44.73	44.32	40.76	37.00	36.69	38.91	29.40	29.09
	30	22	69.31	69.69	57.14	62.78	58.21	40.83	47.98	38.32
	6	25	28.82	34.09	36.78	45.63	29.01	34.57	30.87	21.84
Clover	18	26	87.15	93.06	....	84.72	70.19	57.30	58.50	61.19
	30	27	117.00	123.23	116.66	107.14	98.56	79.84	71.15	66.49
Air			3.82	3.83	8.49	12.16	10.22	9.17	9.22	12.22

TABLE 43—Continued

Crop	Depth Inches	No.	1926 10/19	10/27	11/5	11/12	11/18	11/24	12/3	12/11
			Dates of collection of samples							
	6	1	25.19	26.21	37.20	41.02	29.21	36.35	35.88	27.09
Alfalfa	18	2	85.40	70.14	75.51	74.80	75.64	68.50	64.13	54.89
	30	3	80.77	88.10	66.29	65.78	61.43	53.68	61.81	60.14
	6	6	19.76	15.96	13.80	15.78	12.37	13.60	13.75	10.01
Fallow	18	5	33.44	32.74	27.59	18.77	17.85	19.65	27.80	21.60
	30	4	57.78	51.45	42.91	36.04	36.94	35.11	30.84	29.72
	6	8	16.73	20.18	15.31	--------	13.98	12.77	9.87	10.01
Wheat	18	7	28.11	27.98	18.38	21.15	22.13	22.56	16.75	15.40
	30	9	56.92	46.58	39.80	27.48	23.27	21.01	29.57	28.80
	6	10	27.96	30.90	27.88	33.90	23.64	23.26	25.76	19.69
Clover	18	11	67.67	60.16	51.03	51.99	51.88	50.34	54.59	47.59
	30	12	89.73	83.48	60.25	59.43	57.65	56.37	55.61	50.16
	6	16	29.78	29.51	29.34	42.13	38.61	33.45	31.42	29.63
Alfalfa	18	17	98.42	100.18	80.26	90.49	85.07	82.27	82.68	77.17
	30	18	126.53	125.98	101.02	107.36	108.27	101.45	94.55	85.80
	6	19	18.23	20.99	16.18	17.63	14.71	15.45	15.72	17.15
Wheat	18	21	32.65	33.41	33.17	24.43	15.50	15.43	13.86	23.29
	30	20	58.50	58.28	38.57	36.76	22.48	23.92	23.50	28.75
	6	24	13.79	11.61	17.03	12.98	10.85	12.31	10.81	9.31
Fallow	18	23	22.98	27.11	16.26	19.85	19.37	15.80	18.53	17.08
	30	22	30.39	31.03	22.45	22.91	27.13	25.45	25.41	24.84
	6	25	21.46	23.21	28.98	28.53	27.11	28.45	17.75	16.30
Clover	18	26	66.31	61.43	40.42	39.60	42.28	43.77	40.92	40.03
	30	27	70.53	64.10	48.45	53.31	53.47	52.69	54.07	44.25
Air			12.65	8.50	9.24	4.59	6.20	7.67	8.49	8.54

Crop	Depth Inches	No.	1926 12/20	12/27	1927 1/5	1/12	1/20	1/28	2/4
			Dates of collection of samples						
	6	1	32.80	27.65	26.34	56.51	54.03	62.43	43.34
Alfalfa	18	2	45.70	40.65	49.60	66.58	--------	--------	68.94
	30	3	46.43	41.37	48.78	63.97	72.54	74.51	47.73
	6	6	12.30	10.93	12.27	7.80	10.86	12.95	11.35
Fallow	18	5	19.79	20.29	21.32	21.83	22.49	22.84	19.69
	30	4	28.93	24.41	21.29	27.29	31.42	33.12	28.00
	6	8	--------	--------	--------	--------	--------	--------	--------
Wheat	18	7	17.47	17.95	17.73	15.91	16.30	18.26	25.20
	30	9	28.11	27.32	27.57	31.78	36.15	34.24	24.02
	6	10	18.98	15.67	21.43	25.34	29.26	39.17	32.34
Clover	18	11	40.25	33.65	38.27	38.98	48.34	61.58	45.66
	30	12	50.14	42.11	44.78	41.65	51.75	54.34	44.09
	6	16	31.14	27.29	37.07	57.62	59.79	58.58	47.56
Alfalfa	18	17	60.73	61.08	70.03	70.49	85.95	85.75	68.41
	30	18	73.94	70.80	70.03	76.41	84.31	84.82	83.81
	6	19	16.64	13.23	12.79	23.78	23.98	22.90	13.83
Wheat	18	21	21.18	23.03	22.88	23.02	27.20	27.46	24.59
	30	20	24.21	23.34	22.89	26.09	34.96	33.60	24.93
	6	24	--------	--------	--------	20.73	14.36	9.14	9.21
Fallow	18	23	17.39	18.41	19.05	20.14	19.41	21.35	23.04
	30	22	23.43	23.01	22.88	22.26	27.56	22.87	19.21
	6	25	17.41	16.48	19.06	27.64	23.27	42.15	26.07
Clover	18	26	37.58	28.36	37.36	38.38	38.33	49.78	36.11
	30	27	43.23	31.04	40.38	36.81	42.44	47.40	40.77
Air			7.58	11.50	16.60	6.14	7.71	4.59	8.92

TABLE 43—Continued

Crop	Depth Inches	No.	1927 2/11	2/18	2/25	3/5	3/14	3/23
			Dates of collection of samples					
	6	1	31.69	34.35	24.00	26.14	27.75	22.48
Alfalfa	18	2	48.87	49.53	49.44	46.87	42.98	39.55
	30	3	54.50	51.65	50.05	46.04	46.82	42.98
	6	6	11.41	8.38	7.68	5.37	5.28	5.40
Fallow	18	5	19.82	18.99	18.43	18.41	16.97	10.43
	30	4	30.11	29.62	25.36	25.31	21.88	11.62
	6	8	....	....	....	7.68	9.03	7.71
Wheat	18	7	18.38	19.03	19.96	12.69	14.31	13.89
	30	9	20.29	22.45	23.75	19.18	18.80	19.27
	6	10	24.49	23.19	23.08	25.68	22.55	16.95
Clover	18	11	41.33	41.03	36.60	32.82	32.84	29.28
	30	12	51.48	50.91	42.05	38.48	37.73	31.24
	6	16	40.56	32.65	26.13	27.39	30.24	21.22
Alfalfa	18	17	67.13	60.45	54.17	53.63	53.65	38.60
	30	18	71.29	71.13	59.63	58.95	52.92	49.28
	6	19	13.66	17.93	14.04	11.70	12.85	11.46
Wheat	18	21	20.48	22.54	20.69	20.71	15.48	11.45
	30	20	25.04	30.48	29.25	26.41	26.66	19.07
	6	24	11.36	13.06	12.60	9.74	9.11	6.08
Fallow	18	23	21.58	22.29	20.68	16.88	14.44	12.20
	30	22	18.92	15.04	15.61	15.00	17.50	14.12
	6	25	24.96	22.99	21.98	17.61	13.69	9.35
Clover	18	26	36.35	34.33	38.04	36.72	38.02	26.46
	30	27	41.56	35.45	35.26	35.23	36.48	31.77
Air			5.30	7.62	4.70	6.59	7.98	3.40

Crop	Depth Inches	No.	1927 3/30	4/8	4/15	4/23	5/2	5/10
			Dates of collection of samples					
	6	1	28.92	32.61	28.23	47.29	55.28	56.15
Alfalfa	18	2	51.08	82.92	73.30	99.09	156.44	99.70
	30	3	45.49	54.97	49.53	87.56	132.04	122.56
	6	6	7.48	12.40	8.24	17.52	22.59	17.56
Fallow	18	5	13.09	14.32	12.37	25.91	27.11	23.00
	30	4	13.46	19.30	20.24	33.57	38.43	37.18
	6	8	5.99	12.24	9.06	11.42	20.28	17.56
Wheat	18	7	12.71	18.01	16.87	30.44	36.15	30.54
	30	9	18.72	23.96	18.89	38.47	38.22	38.21
	6	10	26.46	27.66	21.17	40.63	53.00	50.38
Clover	18	11	30.42	58.23	35.88	58.10	84.04	77.26
	30	12	33.77	44.80	34.62	58.51	72.58	73.25
	6	16	29.04	28.30	28.58	65.40	62.53	52.13
Alfalfa	18	17	68.47	82.33	58.60	91.20	127.81	108.45
	30	18	70.75	78.14	62.85	83.32	121.46	122.43
	6	19	18.63	17.43	13.47	15.94	23.93	20.57
Wheat	18	21	14.42	20.46	16.98	24.63	32.06	31.21
	30	20	19.75	26.42	24.67	28.86	43.68	35.04
	6	24	9.08	7.59	9.23	10.19	20.42	13.41
Fallow	18	23	12.13	13.71	10.77	12.85	27.66	22.68
	30	22	16.68	21.21	25.03	27.24	26.56	25.14
	6	25	18.92	20.46	14.62	19.70	49.14	37.94
Clover	18	26	37.90	43.12	46.12	51.88	70.92	65.88
	30	27	45.45	43.91	44.58	49.21	70.83	71.15
Air			3.81	6.81	7.31	10.60	3.77	6.11

TABLE 43—Continued

IRRIGATED

Crop	Depth Inches	No.	1927 5/16	5/23	5/31	6/6	6/13	6/20
	6	1	56.55	34.26	49.21	100.16	113.54	108.90
Alfalfa	18	2	124.33	103.92	125.37	213.01	277.82	258.33
	30	3	142.92	123.29	134.61	154.22	220.12	235.67
	6	6	17.44	19.04	13.77	23.10	21.01	20.88
Fallow	18	5	22.51	44.91	34.48	41.17	31.13	31.74
	30	4	41.30	45.67	43.63	55.44	58.62	47.20
	6	8	25.72	29.39	24.39	33.44	24.87	30.88
Corn	18	7	32.57	36.34	25.59	33.08	40.03	47.50
	30	9	34.02	46.90	51.70	41.51	57.82	48.96
	6	10	45.36	40.80	85.86	130.65	84.17	85.15
Clover	18	11	83.04	81.56	175.30	202.30	231.48	204.88
	30	12	86.79	98.86	135.82	170.88	226.69	214.85

NOT IRRIGATED

Crop	Depth Inches	No.	1927 5/16	5/23	5/31	6/6	6/13	6/20
	6	16	52.81	41.78	39.60	72.93	58.34	59.41
Alfalfa	18	17	118.11	110.21	115.42	118.89	119.18	127.36
	30	18	141.99	139.00	141.01	145.67	172.85	157.29
	6	19	26.93	18.01	19.28	33.73	20.72	21.65
Corn	18	21	30.54	34.37	32.28	33.48	44.07	43.27
	30	20	38.88	39.02	42.36	46.02	41.31	43.27
	6	24	11.27	14.49	11.89	22.02	20.10	15.41
Fallow	18	23	23.22	25.16	35.29	23.18	26.44	30.83
	30	22	32.88	29.36	37.24	36.33	37.53	38.63
	6	25	38.96	29.04	31.61	51.55	38.51	37.75
Clover	18	26	79.04	85.52	87.62	97.42	91.36	90.77
	30	27	82.32	86.85	93.67	98.36	96.90	97.70
Air				7.24	5.03	9.21	6.92	9.23

IRRIGATED

Crop	Depth Inches	No.	1927 6/27	7/5	7/11	7/18	7/25	8/1
	6	1	125.87	100.36	144.15	155.83	111.21	174.10
Alfalfa	18	2	226.65	165.98	280.13	316.21	290.00	270.10
	30	3	221.56	166.62	242.63	258.02	235.06	225.34
	6	6	22.85	20.01	21.33	28.48	24.58	35.63
Fallow	18	5	43.81	48.24	53.39	52.41	53.77	48.86
	30	4	54.17	72.65	66.44	67.44	69.91	85.51
	6	8	30.48	28.84	50.79	72.94	31.01	85.19
Corn	18	7	45.64	62.29	70.89	94.65	86.33	117.72
	30	9	48.00	58.40	73.35	83.68	88.92	132.44
	6	10	73.37	41.50	118.37	98.98	65.51	99.13
Clover	18	11	180.70	126.38	170.41	248.79	191.98	162.65
	30	12	185.33	149.84	177.28	221.24	197.29	198.91

TABLE 43—Continued

NOT IRRIGATED

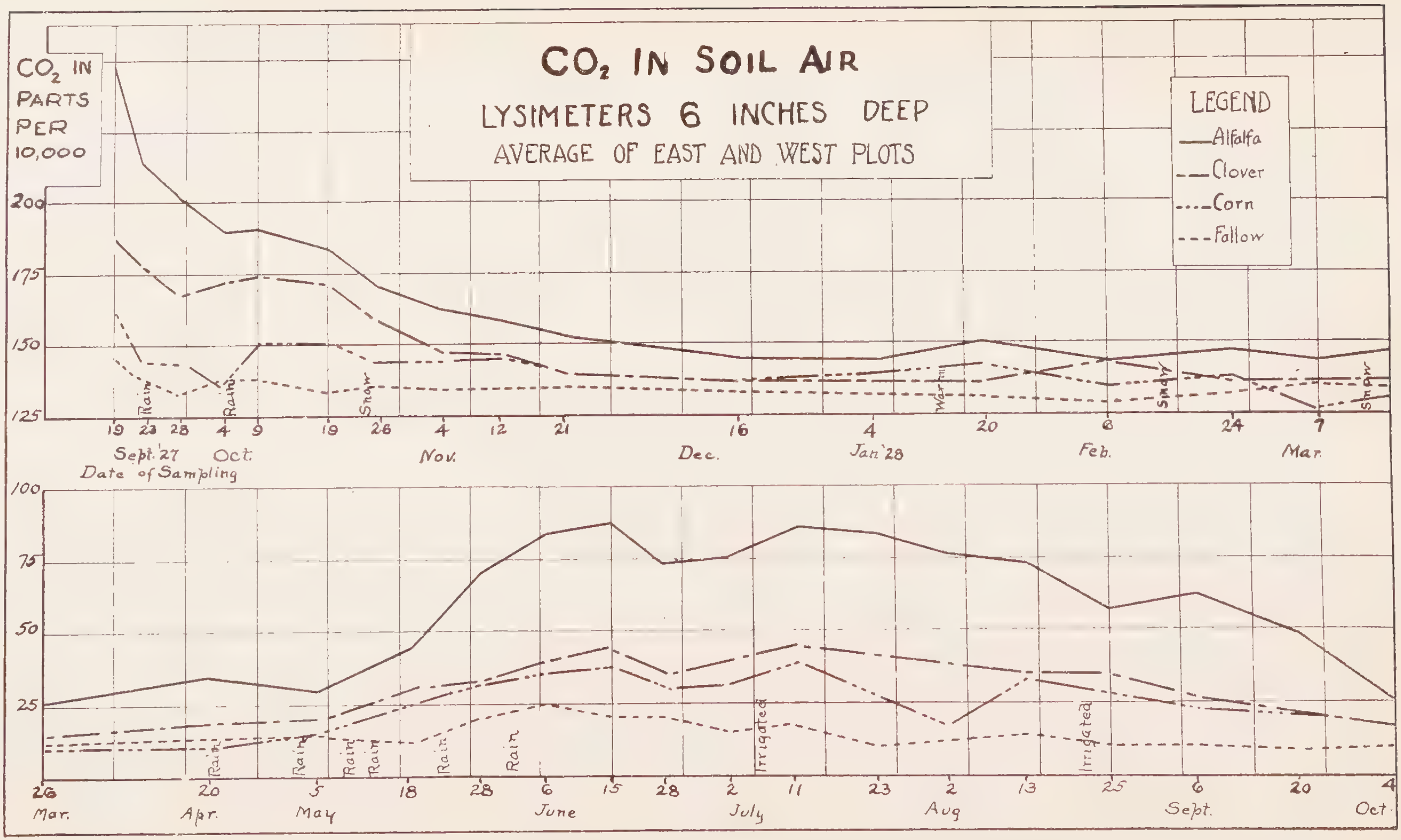
Crop	Depth Inches	No.	1927 6/27	7/5	7/11	7/18	7/25	8/1
				Dates of collection of samples				
	6	16	65.02	44.33	42.34	57.47	53.26	83.99
Alfalfa	18	17	123.93	121.04	112.20	131.24	114.91	139.26
	30	18	149.17	143.31	150.64	160.91	151.74	162.38
	6	19	13.78	19.26	22.84	27.55	37.52	58.27
Corn	18	21	48.55	62.32	67.16	75.78	76.58	107.45
	30	20	58.66	59.26	70.38	82.71	92.94	107.36
	6	24	15.49	19.27	19.82	22.18	18.01	16.98
Fallow	18	23	34.88	35.47	44.97	46.69	45.16	37.83
	30	22	40.32	51.55	55.31	55.11	53.64	54.09
	6	25	38.63	19.25	19.90	29.82	30.68	27.78
Clover	18	26	85.76	73.90	71.94	82.97	66.72	92.51
	30	27	91.16	92.37	83.81	101.49	85.77	86.23
Air				7.70	7.65	7.68	13.83	10.01

IRRIGATED

Crop	Depth Inches	No.	1927 8/8	8/15	8/22	8/29	9/6	9/12
				Dates of Collection of amples				
	6	1	182.75	204.28	139.04	111.56	99.77	92.63
Alfalfa	18	2	298.56	248.07	244.01	209.17	195.34	194.38
	30	3	224.31	200.92	197.05	160.52	153.30	194.16
	6	6	34.04	21.14	19.30	18.44	18.40	40.62
Fallow	18	5	52.64	38.47	40.93	39.99	44.51	47.83
	30	4	85.16	82.37	....	80.94	80.58	75.31
	6	8	60.00	66.00	63.93	38.64	37.55	67.69
Corn	18	7	107.22	91.69	73.29	94.41	95.08	81.68
	30	9	131.53	128.09	116.76	123.39	122.61	119.16
	6	10	93.13	78.62	53.74	64.02	53.19	102.70
Clover	18	11	165.46	169.11	170.92	151.32	146.94	155.45
	30	12	212.56	192.79	157.64	173.88	169.84	184.21

NOT IRRIGATED UNTIL AUGUST 9

	6	16	101.93	132.08	83.21	77.87	61.99	116.14
Alfalfa	18	17	156.89	185.11	247.17	235.24	229.52	173.44
	30	18	162.36	202.03	244.03	238.34	233.35	224.10
	6	19	47.63	67.66	38.81	33.96	32.91	50.31
Corn	18	21	81.27	98.90	96.10	96.32	77.49	73.41
	30	20	103.36	105.89	119.35	115.65	113.92	119.90
	6	24	17.42	13.99	10.79	15.05	16.69	24.31
Fallow	18	23	36.30	31.09	27.76	33.51	28.86	34.75
	30	22	47.92	40.40	50.37	48.54	50.19	47.91
	6	25	42.08	91.67	48.93	35.79	34.90	94.82
Clover	18	26	81.48	117.33	125.13	119.27	87.11	114.02
	30	27	86.08	114.96	143.54	133.89	117.40	123.27
Air			6.14	8.54	7.72	8.32	....	12.32


CO₂ IN SOIL AIR
LYSIMETERS 6 INCHES DEEP
AVERAGE OF EAST AND WEST PLOTS
CO₂ IN PARTS PER 10,000
LEGEND
Alfalfa
Clover
Corn
Fallow
200
175
150
125
100
75
50
25
Rain
Snow
Warm
Irrigated
19 23 28 4 9 19 26 4 12 21 16 4 20 6 24 7
Sept. '27 Oct. Nov. Dec. Jan '28 Feb. Mar.
Date of Sampling
26 20 5 18 28 6 15 28 2 11 23 2 13 25 6 20 4
Mar. Apr. May June July Aug Sept. Oct.

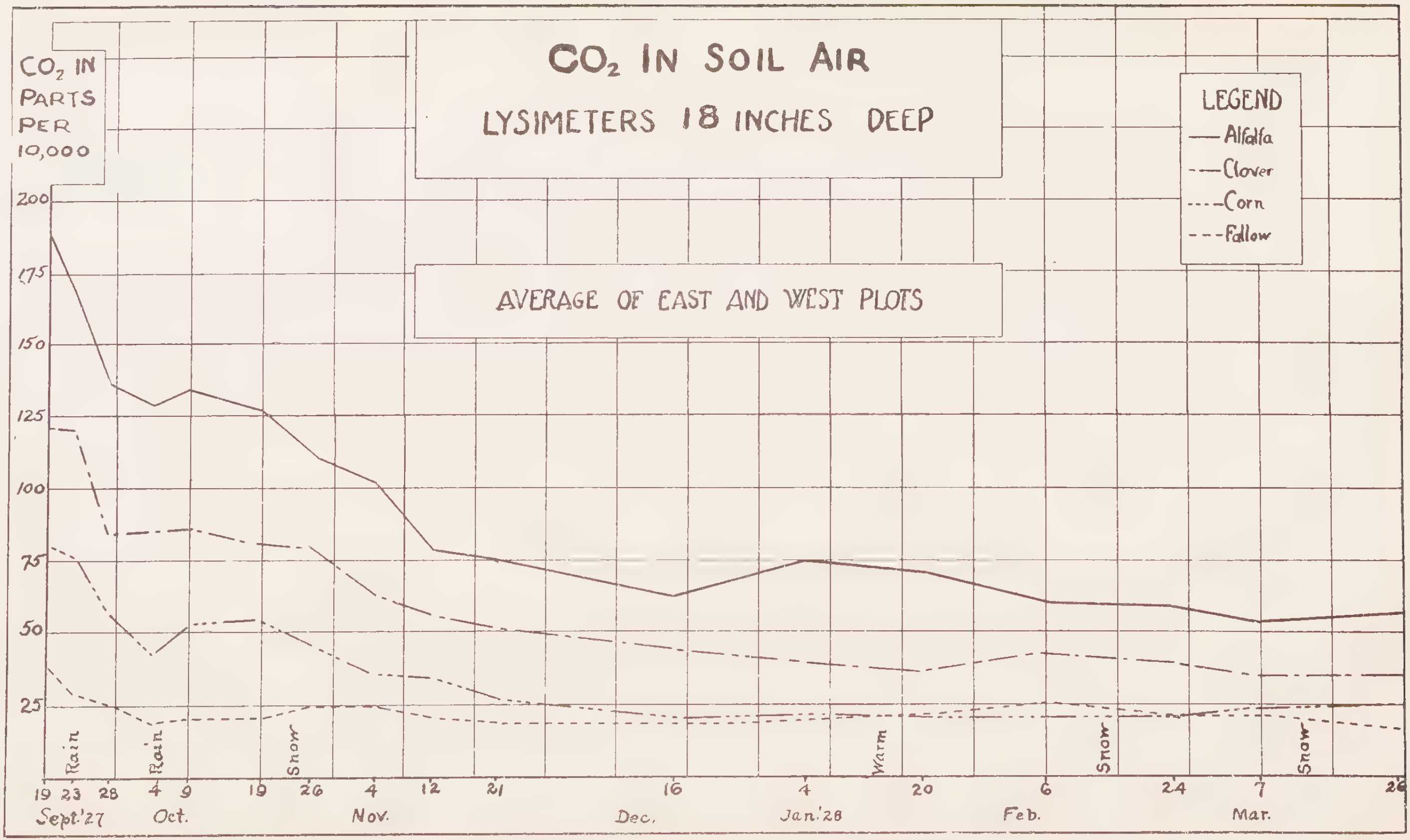
The graphs show in a striking manner the variations in the amount of carbon dioxid due to temperature and moisture during the development of the plants, also the change at maturity. These facts go far toward explaining observations made by ranchmen on the different effects of irrigation when applied only a few days, possibly hours, apart. The following instance was presented to me for an explanation:

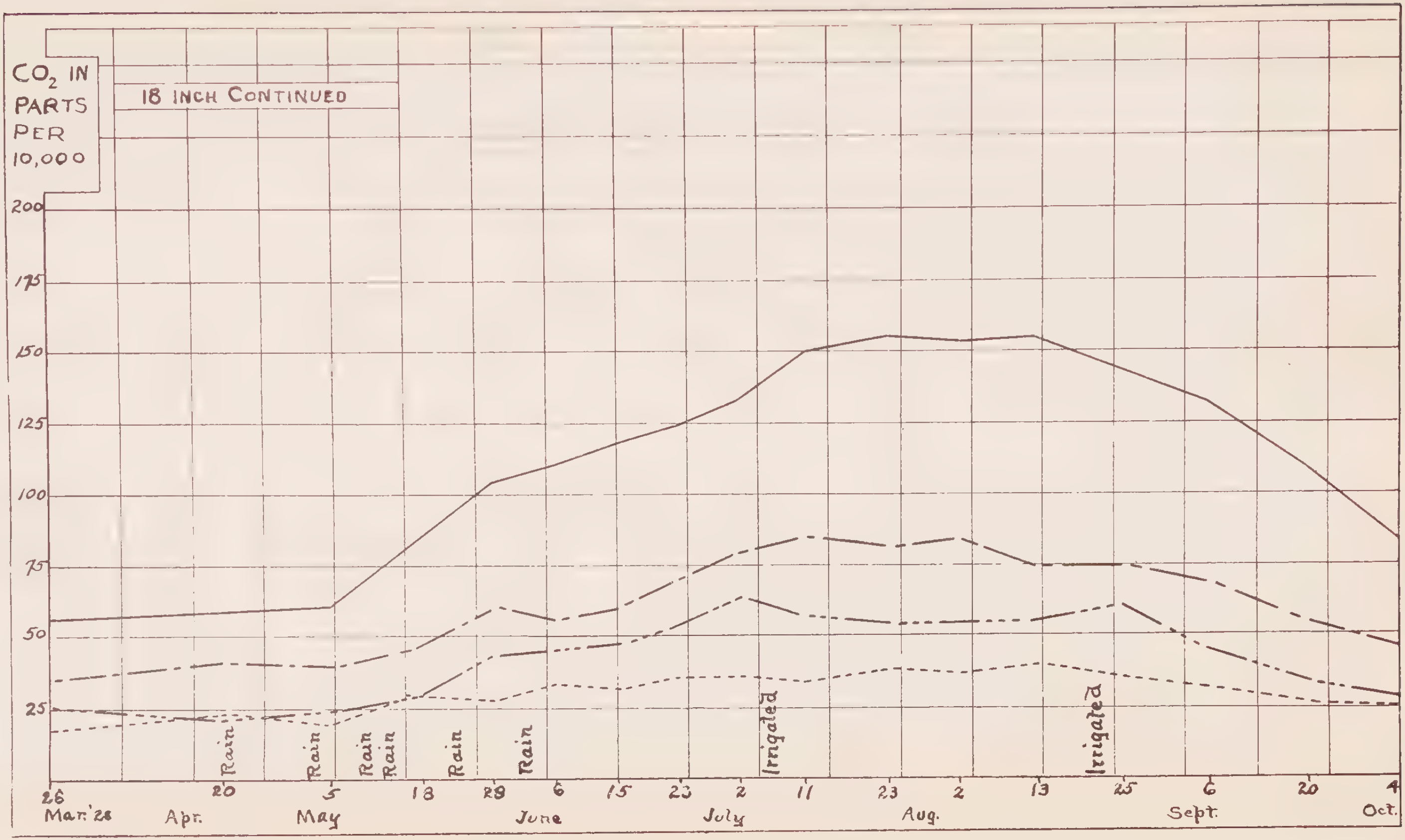
A potato-grower was irrigating his field of potatoes but could not finish it before night. He was entitled to a good run of water and did not think there was any urgency requiring night irrigation, so he shut off the water and finished the task the next day. He asserted that the portion irrigated the second day was outdistanced both in growth and yield by that irrigated the first day.

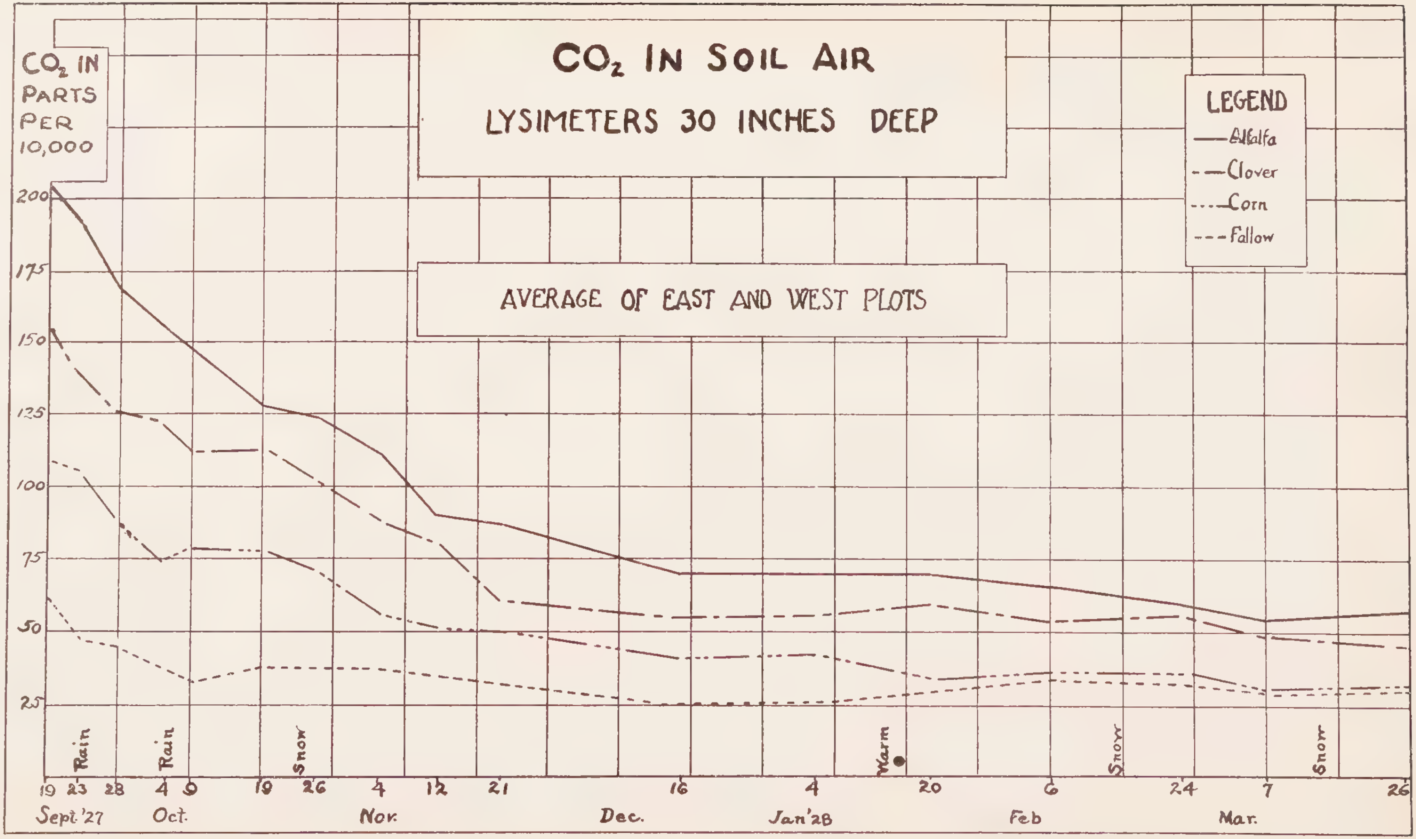
Some years ago the writer observed an oat field a part of which received some water one night due to the clogging of a lateral than ran beside it. This water was turned off the next morning. The whole field was irrigated a few days later. That portion that received the accidental night wetting grew rapidly and made a fine crop; one could at all times after that recognize all the irregularities in the boundary of this wetted portion. The rest of the field never recovered.

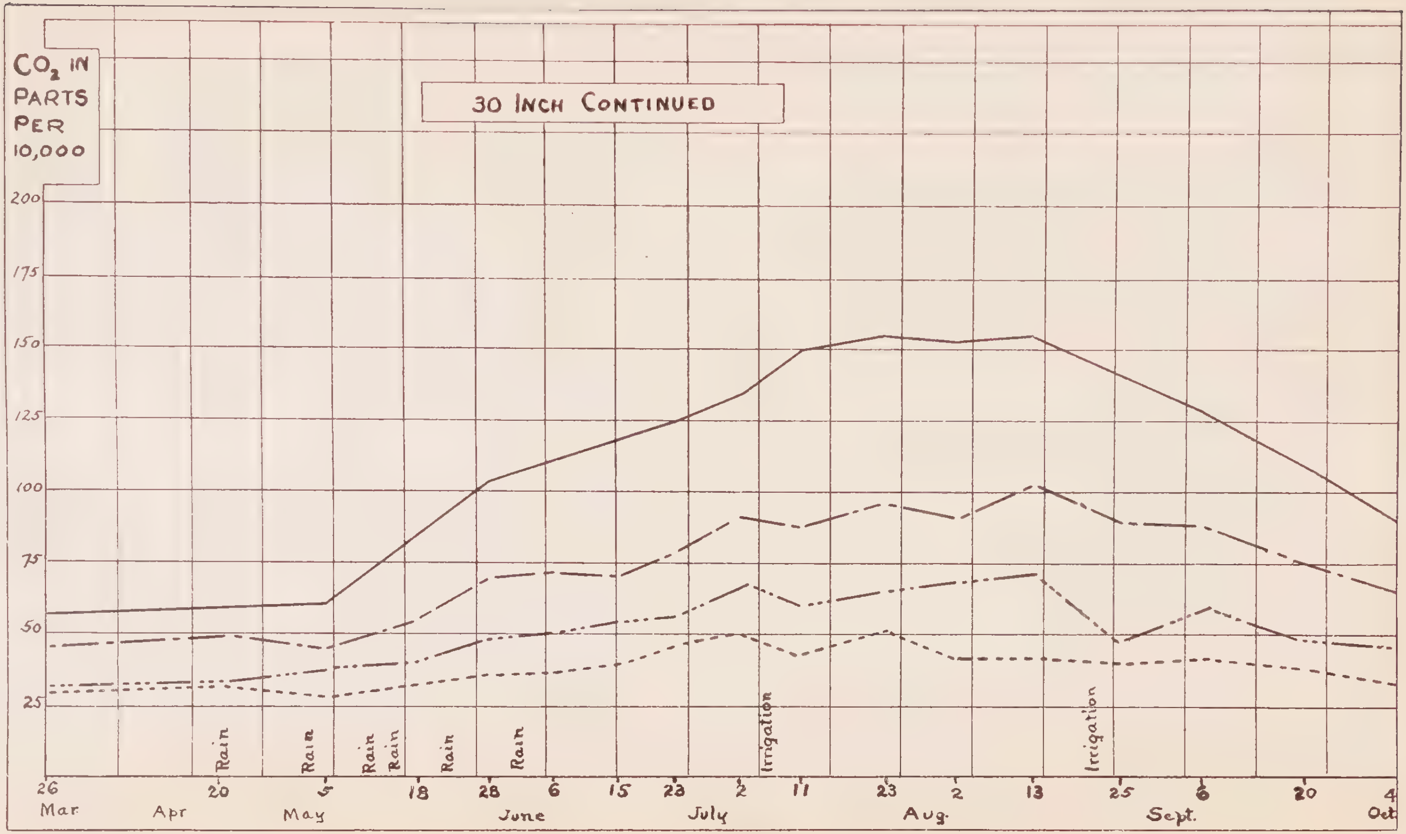
Our wheat in June, 1926, was subjected to a period of warm, dry weather. The carbon dioxid in the soil air under the wheat on 21 June averaged, for the three lysimeters, 129.2 parts per 10,000; by 6 July the average had fallen to 79.0 parts. There is no note to the effect that the wheat showed any indication of a lack of water, but the plots were irrigated on 6 July and the carbon dioxid increased immediately and continued to do so, till on 13 July there was an average of 130.2 parts per 10,000. The plants had ceased growing but on the application of water they resumed their vegetative functions and practically doubled the amount of carbon dioxid in the soil in 7 days. A very light rainfall between 21 June and 6 July would have changed our results. On the other hand had we delayed the irrigating for a few days it is very doubtful whether the plants would have been able to respond. This as in the cases of the potatoes and oats, was the critical point in the development of the crop.

There is a practical side of this, to wit, if the development of the carbon dioxid were followed and found to be falling before the plants were fully developed it would indicate an abatement or falling off in the development of the plant and show a need of immediate irrigation. In other words an abundant and


CO2 IN SOIL AIR
LYSIMETERS 18 INCHES DEEP
AVERAGE OF EAST AND WEST PLOTS
LEGEND
Alfalfa
Clover
Corn
Fallow
CO2 IN PARTS PER 10,000
200
175
150
125
100
75
50
25
Rain
Rain
Snow
Warm
Snow
Snow
19 23 28 4 9 19 26 4 12 21 16 4 20 6 24 7 26
Sept.'27
Oct.
Nov.
Dec.
Jan.'28
Feb.
Mar.


CO$_2$ IN PARTS PER 10,000
18 INCH CONTINUED
200
175
150
125
100
75
50
25
Rain
Rain
Rain
Rain
Rain
Rain
Irrigated
Irrigated
26 Mar.'28
20 Apr.
5 May
18
29
6 June
15
23
2 July
11
23 Aug.
2
13
25
6 Sept.
20
4 Oct.


CO_2 IN SOIL AIR
LYSIMETERS 30 INCHES DEEP
AVERAGE OF EAST AND WEST PLOTS
LEGEND
Alfalfa
Clover
Corn
Fallow
CO_2 IN PARTS PER 10,000
200
175
150
125
100
75
50
25
Rain
Rain
Snow
Warm
Snow
Snow
19 23 28 4 9 19 26 4 12 21 16 4 20 6 24 7 26
Sept '27
Oct.
Nov.
Dec.
Jan '28
Feb
Mar.



CO₂ IN PARTS PER 10,000
30 INCH CONTINUED
200
175
150
125
100
75
50
25
Rain
Rain
Rain
Rain
Rain
Rain
Irrigation
Irrigation
26 Mar
20 Apr
5 May
18
28 June
6
15
23 July
2
11
23 Aug.
2
13
25
6 Sept.
20
4 Oct

continuous development of carbon dioxid indicates a vigorously growing plant and this will continue until the plant is ready to ripen or is mature. At this point the carbon dioxid will begin to fall. If the plant is otherwise healthy and well fed and this development of carbon dioxid is interrupted it shows decidedly the need of water. The water supply and the tempreature are the two factors controlling the evolution of the carbon dioxid; these control the growth of healthy, well-fed plants. We cannot control the temperatures on a large scale but under irrigation we can control the water supply.

By following the amount of carbon dioxid in the soil we would be able to ascertain when our crops imperatively require irrigation. Our wheat on 6 July, 1926, was in serious danger for it had practically stopped growing and had we not irrigated it the crop would have been cut short; but irrigation after this date was not needed. The next time that the carbon dioxid fell the plants were maturing and irrigation would have been useless, even ill advised.

This land will be studied further to see how it comports itself under cropping to wheat and fallow cultivation.

SUMMARY

Original Conditions

Nitrate of soda applied to the land experimented with at the rate of 250 pounds per acre was injurious to a wheat crop. Phosphoric acid and potash applied in large quantities did not produce any perceptibly beneficial results. According to these results the land was capable of producing maximum crops without the addition of the usual fertilizers.

Interpretations relative to productiveness cannot be based on aqueous extracts of these soils. They usually contain potash, for instance, which has been brought into solution by the process of extraction. Phosphoric acid is seldom reported as present in them; sometimes it is reported as absent.

In the production of wheat, potash tends to bring about mealiness, the nitrates flintiness, while phosphoric acid does not seem to have any direct influence upon these characteristics of the crop.

General Basis for This Study

This study is based upon the generally observed beneficial effects of clover and alfalfa in a rotation and to a less extent upon those of wheat. Alfalfa is considered our principal forage

crop. We do not attempt to estimate the mechanical effects of an alfalfa crop. A good stand varies from 225,000 to 525,000 plants to the acre but fewer plants will produce fully as good a crop of hay. In our soils the roots will average .5 inch in diameter and 7.5 feet long. We have seldom found them less than 6 feet, but often 10 to 12 feet long. We make no effort to estimate what the purely mechanical effects of such a stand and mass of plants may be.

GREEN CROPS PRODUCE AT LEAST FOUR-FIFTHS CARBON DIOXID IN SOIL

The carbon dioxid in the soil atmosphere is partly due to the soil population other than the growing crop, but the clover, alfalfa and other crops observed produce four or five times as much. Some members of the soil population may use this carbon dioxid but our green plants seek their supply in the atmosphere.

ROTATION ADDS NO PLANT FOOD

The object of rotation is to increase the productivity of the land. The addition of fertilizers is for the same purpose; the latter actually add plant foods to the soil. A rotation of crops cannot do this directly. If the crop in rotation uses the nitrogen of the atmosphere in building its nitrogenous compounds, then there may be an addition of nitrogen. This is not true of phosphoric acid or potash. The crops get their supply of these from the soil and at the most can only change the form in which they are present in the soil.

Wheat does not take its nitrogen from the air and any benefit resulting from this as a member of a rotation must be produced in some other way. We record an exceptional but instructive instance in which it produced very good results. Alfalfa produced the same kind of results in a greater degree. Alfalfa is a heavy feeder and the crop is not returned to the soil—only about one-fifth of it, which is lost in hay making. Nitrogen is different from potash in that it is a variable quantity whereas the total quantity of potash in a soil may be diminished but not increased by natural processes. This is also true of phosphoric acid. We may change these from insoluble to soluble forms but we cannot add them by any rotation of crops.

QUESTIONS INVOLVED

The questions involved in this study are: The effects of a rotation on the mechanical and sanitary conditions of the soil;

its relation to the total and nitric nitrogen; its relation to the available potash in the soil.

These cover the scope of this study. The phosphoric acid has not been included except incidentally. The first subject, the mechanical and sanitary conditions of the soil, is of great, perhaps, the greatest importance, but we have been compelled to stress the second and third.

Carbon Dioxid and Water a Good Solvent

It is an old assumption that plants bring their mineral foods into solution by acid excretions. They excrete large quantities of carbon dioxid, soluble in water with the formation of carbonic acid which is capable of effecting this object. We used, experimentally, finely ground felspar. Observations have been made also on the soil.

Tilth Must be Our Measure of Mechanical Effects

Under the subject of sanitary conditions we shall study the fixing and nitrifying efficiency of the soil before and after plowing under the crops. Further than this we shall not be able to go. We have no measure at all of the mechanical condition. These two features are of the greatest importance but of the latter we must be content with our judgment of good tilth, etc. Beyond this we have to rely upon analytical results which are satisfactory as far as they go.

Fertility of the Soil

The productive power of this soil is good. Measured by its yield of wheat, which is from 40 to 65 bushels per acre, all forms of plant food are reasonably abundant. The quality of the grain produced judged from the standard of flintiness, is good, but better after a year's fallow than when planted after grain, wheat or oats. These points give an intimation of the supply of nitrogen as well as of other crop requirements.

Accumulation of Nitrogen Doubtful

The accumulation of nitrogen in alfalfa land is not large enough in a 4-year period to answer decisively the question of increase. We do not know what the actual nitrogen content of the 4-year-old alfalfa field was when it was laid down to alfalfa but the land had been used as a horse run for 10 or 15 years before that. The differences in percentages are so small and the variations in nitrogen content of samples are so great even in

such as have been taken with great care, that one fears to use averages as indicating the real amounts of nitrogen in different plots of ground in comparatively small tracts of level land. In the case of our alfalfa land we are almost compelled to do this. The general average for the tract of land of which this alfalfa field forms a part is 0.1448 percent to a depth of 1 foot. The average of 150 samples taken to a depth of 1 foot was 0.1263 percent, and of 60 samples taken in this alfalfa field to a like depth, it is 0.1325 percent. The difference between the last two averages in favor of the alfalfa field is so small that its value is doubtful.

We compared a pair of alfalfa plots with a pair of fallow ones. A fallow plot was adjacent to each of the alfalfa plots. This was an attempt to get land as nearly the same as possible. At the beginning of our experiments there was a difference of 0.0106 percent in favor of the alfalfa plots. At the end of 2 years we found a difference of 0.0143 in favor of the alfalfa or an increase of 0.0037 percent.

This again is too small to be satisfactory. Even the 0.0143 percent without any allowance for the initial difference in favor of the alfalfa, would be of doubtful force in the general question for it is too small to account for the effects produced by such a rotation.

All changes tending toward an increase in the total nitrogen are at or near the surface of the land.

Total Nitrogen in Land Planted to Different Crops

The range in the total nitrogen in land planted to different crops gave us corn (maize) 0.1275, sorghum 0.1244, winter wheat 0.1197, spring wheat 0.1333, spring wheat dressed with superphosphate 0.1456, and spring wheat dressed with potassic chlorid 0.1387 percent. The last figures suggest that non-nitrogenous fertilizers may affect the nitrogen content of the soil. We believe that it does by changing the soil conditions and encouraging the development of micro-organisms.

Relations of Nitric Nitrogen

The relations of nitric nitrogen are different from those of the total nitrogen. The average nitric nitrogen shown by 53 samples from the alfalfa field taken 6 inches deep was seven parts per million. A like number of samples taken to the same depth from the fallow plots showed eleven parts per million. In the second 6 inches, 7 to 12 inches. it was two p. p. m. under the alfalfa and eight p. p. m in the fallow land.

Nitrification Depressed by Crops

The data given for the sodic nitrate equivalent to the nitric nitrogen found under wheat, show the relation of this crop to its formation. The soil's ability to nitrify was not destroyed, but was depressed. It required the lapse of several months before the soil regained its nitrifying power. The effects on the nitrogen-fixing efficiency was not studied in this connection but it has been proved that this soil ordinarily has a high fixing efficiency and it is probable that this is affected in the same sense that the nitrifying efficiency is affected, namely, that it is depressed during the growth of the crop but is not destroyed.

The Small Amount of Nitrogen Added by Alfalfa Not Easily Changed

The small amount of nitrogen added to the soil by alfalfa is not sufficient to be of much importance nor is its character such as to undergo changes or it probably would not show its presence as it would have disappeared in the form of nitrates.

Benefits of Alfalfa Stated

We hold that the benefits accruing to a soil planted to alfalfa are due to its mechanical and sanifying effects and to its production of large quantities of carbon dioxid throughout the season whereby the available potash in the soil is very perceptibily increased.

The Chemical Effects of a Rotation

The soils were studied from the standpoint of their chemical composition in an endeavor to ascertain what changes are effected in this respect by the rotation. The preliminary experiments showed that growing plants, grasses and clover, kept the soil air and solutions charged with carbon dioxid. Experiments recorded in Bulletin 319 and others demonstrate that the mineral constituents of the soil containing potash, usually considered as non-participant in questions of soil fertility, yield relatively large amounts of potash to solutions of carbon dioxid. We considered it as practically demonstrated that this would be the action of crops upon the soil. Wheat keeps the soil flooded with carbon dioxid for a short time and uses a good deal of potash, apparently more than it sets free. Clover and alfalfa produce throughout the season almost as much carbon dioxid as wheat at its maximum and continue to produce some throughout the winter. While they are both heavy potash feeders they

do not use as much as they bring into solution. To ascertain this became a general purpose had in view.

ABSORPTION COMPLEX IN OUR SOIL

We further wished to find out whether a complex exists in our soil that will exchange its bases with ammonium chlorid, and the amount of these bases. The general composition of our soil was established by conventional methods. We have recorded the results obtained, but depend, for the most part, upon other methods for results to be used in our study.

CALCAREOUS AGGREGATES

The soils are calcerous, the subsoils strongly so. Much of the carbonate of lime is attached to the soil particles as films or incrustations and forms a good portion of the clay separated in the mechanical analysis. These separates show some points of interest on being treated with acetic acid and then with ammonium chlorid. The ammonium fixed increases rapidly with the fineness of the separates.

The soil yields much potash to water on a short digestion and its degree of fineness plays a part in its replacement reactions.

In examining these soils we used water, dilute hydrochloric acid, and dilute acetic acid as solvents. The hydrochloric acid when standardized and added only in slight excess of that required to dissolve the calcic carbonate, can be used very well but acetic acid was used in preference. It is convenient in this connection to distinguish between aggregate and complex. The complex meaning that portion of the soil which contains bases replaceable by ammonium, is evidently a little more stable than the calcareous mass forming the aggregate even though it may be contained in it. There is much soluble potash in our soil that is not contained in the complex; for instance, the soluble potash in our fallow land was 703 p. p. m.; of this 324 p. p. m. were found in the ammonium chlorid solution, that is, it had been held in the complex whereas 379 had gone into solution in the acetic acid extract. It is true that the complex may have been altered by reactions between it and the acetates formed during the treatment with acetic acid, but we assume that these reactions did not materially affect the structure of this complex in which lime is the predominant base, representing 8 or 10-milligram equivalents out of 13 which is about the average milligram equivalent of the ammonium fixed by the soil. The ammonium-milligram equivalent is not affected by previous

treatment with dilute acid. While a continued treatment of the complex with a calcic-acetate solution might cause an exchange of potassium for calcium, a study of our results will show that we have no strong reason for supposing that such an exchange took place.

In our case the aggregate is decidedly calcareous which is shown, perhaps in an exaggerated degree, by the amount of lime in the clay portion of the mechanical analysis. More than half of the potassium exists in the aggregate and is dissolved when this is broken up or is exchanged for lime in the complex.

THE COMPLEX AND AGGREGATE NOT THE SAME

The aggregate and complex are separate forms in the soil. Treatment with dilute acids removes the salts in the aggregate but does not affect the complex, at least it does not affect the amount of ammonium fixed unless the acid is too strong when the complex is partially or wholly broken up. Careful treatment with dilute acid divides the soluble potassium into two portions, one representing very easily soluble potassium, probably not existing in the complex and the other slightly less soluble and forming a part of the complex. The former is the larger portion in our soils.

PHOSPHORIC ACID IN SOIL IS SOLUBLE

The phosphoric acid goes into solution readily in dilute hydrochloric acid and is somewhat soluble in the acetate solution. This does not agree with the statements that we find in regard to this subject. The phosphoric acid is soluble in acetic acid, also in water. In acetic acid solutions we found up to 60 p. p. m. and in water 14 p. p. m.

The phosphoric acid was only incidental to our subject, i. e., a study of how the nitrogen and potassium were affected by our rotation. We have summarized our observations on the total of these. The water-soluble potassium under the respective crops was determined throughout the season of 1927.

WATER-SOLUBLE POTASSIUM IN SOIL UNDER CROPS

Our mountain waters which owe their mineral content to the action of natural waters on the mountain masses, for the most part naked rock, suggest that the same agents, carbon dioxid and water, will act in the same manner on the soil particles, things distinct from the aggregates and complexes in the soil. We have dealt with the latter up to the present but we

change our point of view because we find our available supply of potash under the clover and alfalfa actually increased though these two crops are heavy users of this element. We find an increase of this in the aggregates themselves. The agents considered are the felspar, the moisture, however maintained, and the carbon dioxid given out by the plants.

In order to follow the water-soluble potash in the soil under the crops, we adopted a method suggested and used by the Bureau of Soils of the United States Department of Agriculture.

Our preliminary results justified us in assuming the presence of large quantities of carbon dioxid under the crops. We assumed that the water-soluble potash, or better, potassium, would bear a relation to the carbon dioxid in the soil atmosphere. In the fallow there was a moderate supply, under the wheat a big supply for a little while, but under the clover and alfalfa a great deal all the while, even in the winter season. There was no crop on the fallow land to use up any potassium rendered soluble except the soil population. The wheat seems to have used more than the carbon dioxid set free. The clover and alfalfa used a great deal for the crop was good but there was an excess. The gain was 800 pounds of potash in the top 2 feet of soil in 2 years. This is equal to 1600 pounds of potassic sulfate.

TWO UNLOOKED-FOR EFFECTS

The effects of plowing under the crops were surprising in two respects; both the carbon dioxid and the soluble potassium fell. The change in the amount of the carbon dioxid or carbonic acid in the soil may have affected the solubility of the potassium. We were careful about excluding this source of error in the water used for extraction. When carbonated water was used the potassium was quite readily soluble which suggested the statement just made, that the falling off in the amount of soluble potassium may have been due to the falling off in the carbon dioxid. Carbonated water dissolved more than twice as much as carbonic-acid-free, distilled water.

EFFECT OF PLOWING UP THE CROPS ON NITRIC NITROGEN

The amount of nitric nitrogen in the different plots immediately began to change after they were plowed. The greatest aggregate change was in the fallow for in this the change involved the whole 3 feet sampled whereas in the others the change was confined to the top 6 inches. The observation that the changes affecting the nitrogen is usually confined to a shallow top section has been made repeatedly.

ACTION OF CARBON DIOXID STATED

The action of carbon dioxid and water on the soil particles is given in Part II of Bulletin 319 where it was shown that potassium is the mobile constituent in the soil as well as in the felspar; this means that it is taken into solution in larger quantities than any other element. This statement does not include carbonate of lime which dissolves freely but this fact does not alter the action of the potash minerals in the soil.

The carbon dioxid in fallow land is much more abundant than in our atmosphere and varies within a moderate range. This is not so under cropped soils; the range is wide. The usual amount in our atmosphere is 0.03 to 0.04 percent; under wheat at its period of most vigorous growth it may be nearly a hundred times as much and almost as much under alfalfa for a long time. The amount varies with the stage of growth and the rate of development. The amount increases till the plant reaches maturity which is before the ripening period. In case of the wheat plant it continues downward as the ripening proceeds, but in clover and alfalfa the succeeding growth interferes and a development of carbon dioxid is re-established, but even in these plants there is a period at the time of maturation when there is a falling off in the amount of carbon dioxid developed. Our practice is to cut the alfalfa at this period because the plants are at their maximum and because the plants provide for a succeeding growth which starts at this time. The practice is based upon certain considerations of plant maturity and is in the main a wise one, when for any reason, and there are good reasons for cutting alfalfa earlier than is our usual practice, we change the time and extent of the variation of the carbon dioxid in the soil atmosphere.

The constant increase of carbon dioxid in the soil under healthy, well-fed and watered plants is the natural result of development. When the plant reaches maturity and begins to ripen, the carbon dioxid begins to fall and continues to fall till it reaches the level of the fallow land. In the case of the clover and alfalfa the plants provide for their continued existence by producing new aerial parts, but up to this point they behave in the same manner as other plants. There are two things in our case that may interrupt this continuous increase, cold weather and a lack of water; the former we cannot, the latter we can control. Anything that impedes the growth of the plant is followed by a decrease in the carbon dioxid in the soil air and any such decrease during this period, not due to cold weather, indicates the need of irrigation and a critical point in the develop-

ment of the plant that may easily be passed and often is at this point.

The effects of clover and alfalfa in a rotation are not to increase the nitrogen supply but to add to the supply of the water-soluble potassium and to improve the mechanical and sanitary conditions of the soil. They effect the former by maintaining an abundant supply of carbon dioxid in the soil air throughout their occupancy of it.

Cultivating fallow is more effective in increasing the nitric nitrogen in the soil than either clover or alfalfa. It maintains a moderate, but, within certain limits, a constant supply of carbon dioxid in the soil air which brings potassium into solution. But a very much smaller amount of carbon dioxid is maintained in fallow than in clover or alfalfa land.

The carbon dioxid is the effective agent in bringing the potassium into a soluble form.